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NOTES ON THE FORESTS ON THE EAST COAST OF HUDSON BAY AND JAMES BAY

BY

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HELSINKI—HELSINGFORS 1950

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CONTENTS:

Introduction.

The forest-botanical notes below were made during a summer expedition by canoe (with outboard motor) from Rupert House to Great Whale River, July 7th to August 26th 1947. The expedition was jointly sponsored by the National Museum of Canada and the Arctic Institute of North-America. A short account of this »Canadian-Finnish Hudson Bay East Coast Expedition» appears in Arctic, Vol. 1, No 1 (1948).

The members of the party were: Mr. W. K. W. Baldwin, Botanist and industrious manager of the expedition, Ottawa, Dr. E. H. Kranck, Geologist, Helsingfors, now in Montreal, Mr. James Kucyniak, Bryologist, Montreal, Dr. Risto Tuomikoski, Helsingfors, and the author, scientific leader of the phytogeographic party. An itinerary of the journey appears in Table I below.

I wish to express my sincere gratitude to all the above mentioned friends and members of the party, to Chief Curator Dr. F. J. Alcock, and to the Chief

Botanist of the National Museum of Canada, A. E. Porsild, who had so much trouble in organizing this expedition. Thanks to a grant-in-aid from the Arctic Institute in 1947, the author could take part in this expedition. The grant-in-aid was so generous that it made it possible for me to take my colleague, the well-known bryologist Dr. Tuomikoski, with me. For this grant-in-aid I express my thanks especially to the Director of the Arctic Institute, Dr. A. L. Washburn, Montreal. He and Mr. A. E. Porsild and their staff helped us, the Finnish members of the party, in every possible way.

The phanerogams mentioned in the text have in all critical cases been determined by Mr. Porsild. The mosses mentioned in the sample plot descriptions were determined by Dr. Tuomikoski, the lichens by Dr. Sten Ahlner, Sweden, and Dr. Veli Räsänen, Finland. The increment cores were carefully measured by Mr. Fritz Bergman, Helsingfors. For all this aid, including the aid from the Hudson's Bay Co's employees and the Botanical Institute in Montreal, I here express my deep gratitude[1].

The first part of this paper includes only material gathered on the coast of Hudson Bay and James Bay S of Great Whale River. The second part consists of forest-botanical notes from the Great Whale River area. The third part deals with the tree growth problems in the area.

Helsingfors, February 2nd 1950.

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[1] I regret that Dr. E. H. Kranck's paper (1950) on the geology and geography of the coast could not be used here; my paper was already in page-proof. Of forest-botanical interest in his paper are i. a. the notes on the dunes at Great Whale River.

Part I.

1. General Notes on the Geography of the Coast Area.

The east coast of the Hudson Bay has been described by several authors. I refer especially to the important papers by BELL (1879) and LOW (1889, 1896, 1900). In their geological reports these famous Canadian geologists also include a number of observations concerning forests and general botany. In recent years the coast has been visited i.a. by MANNING (1946) and the authors included in his list of references. In this issue of Acta Geographica appears a large geological and geographical description of the area visited by the Canadian-Finnish expedition in 1947 (KRANCK 1950).

The places visited during the Canadian Finnish expedition 1947 appear from Map 1.

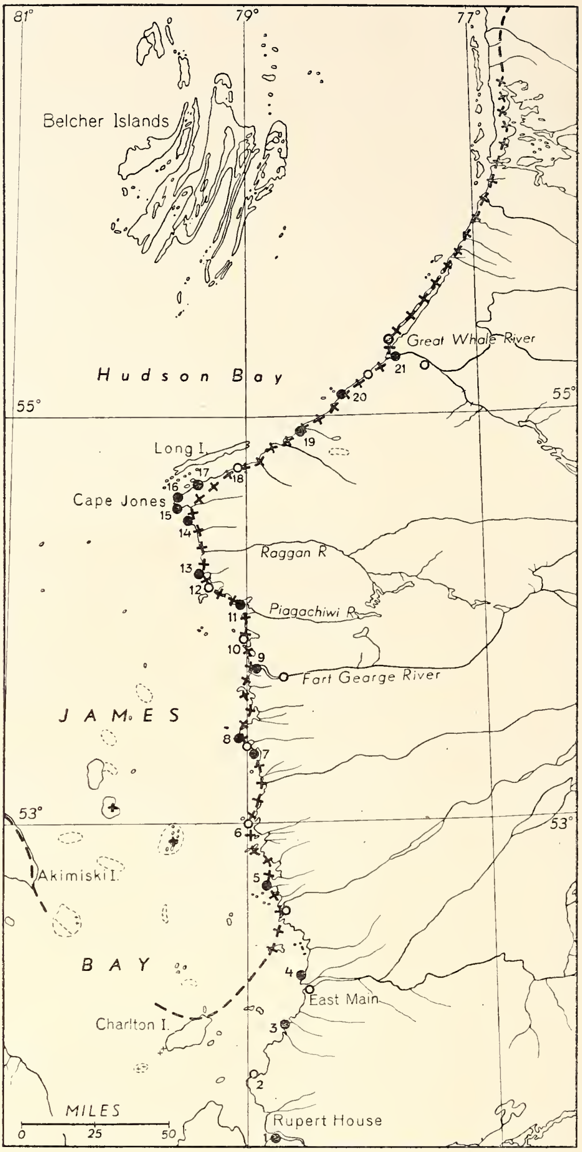
The eastern coast of James Bay is low. The highest marine limit stretches far inland, the coast zone is flat and covered with clay and sand. The mainland bedrock is, in general, granite and granite-gneiss. Along the coast there are several low skerries, sometimes forming large archipelagos, similar to the better known and often described archipelagos of Archaean bedrock in the Baltic Sea. Many of the islands are, according to Dr. E. H. KRANCK, of »drumlin» character, i.e. they are low islands, 24—30 feet above sea level, entirely covered with gravel or sand.

From Cape Jones northwards the coast is higher and rocky, the spruce forest comes down to the coast in sheltered valleys between the cliffs, see Fig. 3. The mainland coast from Long Island Sound to the Great Whale River is mainly granite, but a narrow zone of Precambrian limestone stretches along the coast zone. The islands are all Precambrian limestone and diabase. But also on the granite bedrock of the mainland coast there is often glacial till of sedimentary origin.

The annual mean temperature varies between approximately —1.7° C (Rupert House) and about —5° C (Great Whale River). The monthly mean temperatures at Fort George and Great Whale River appear on Diagram 1. For comparison the stations Moosonee and Fort Churchill are included on the Diagram.

For data regarding the climate, see CONNOR 1938 and VILLENEUVE 1946. The winter climate is described by HARE and MONTGOMERY 1949.

There is, of course, a great difference in temperature between the islands and the coast and between the coast and inland at the same latitude in



Map. 1. The route of the Canadian Finnish Hudson Bay Expedition 1947. The black dots indicate main night camps (the numbers refer to Table I); the open dots other places visited. The +—line marks the approximate maritime tree-line in the area. Note the remarks on pp. 13—14 regarding white and black spruce on the James Bay islands.

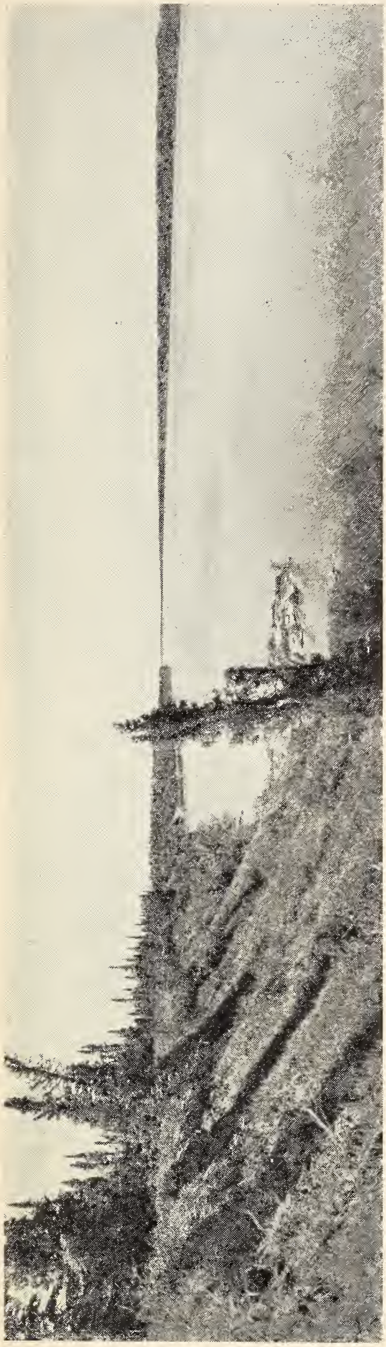


Fig. 1. George River, near sample plots 3 and 4. Photo E. H. Kranck.

Fig. 2. Island N of the mouth of Beaver River. Note the characteristic low ridge and the spruce patches in shelter from the sea wind. Photo E. H. Kranck.

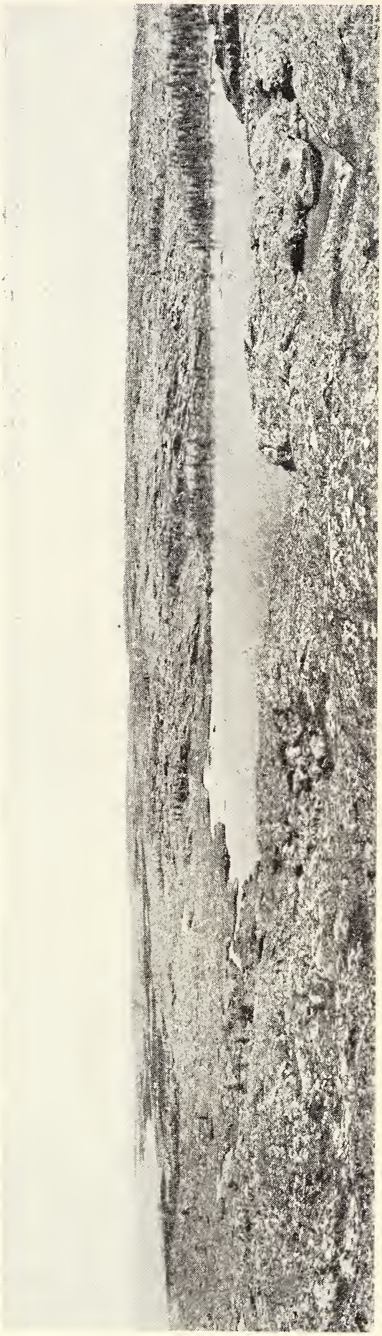


Fig. 3. From the mainland coast of Long Island Sound, i.e. locality 18; see p. 23. Photo E. H. Kranck.

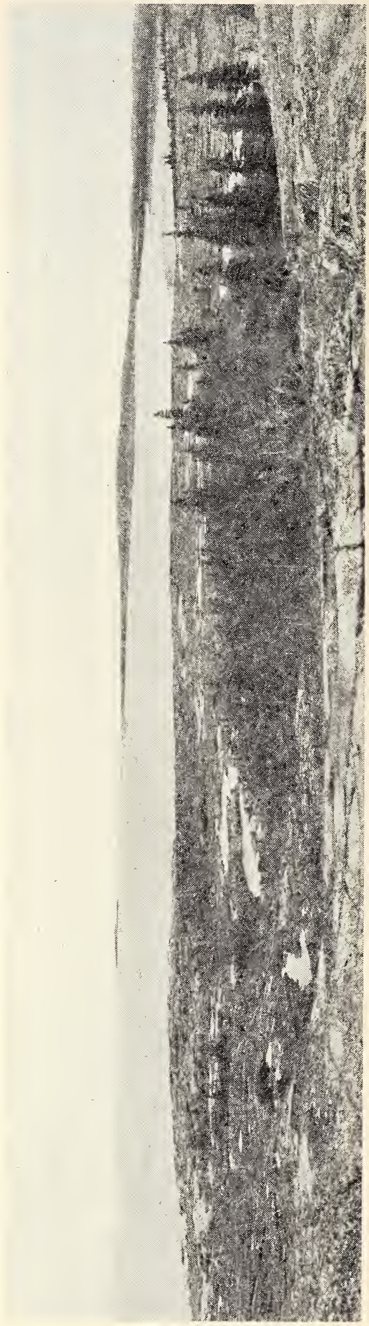


Fig. 4. S of the mouth of Great Whale River. Photo E. H. Kranck.

Table I. Itinerary of the journey in 1947.[1]

Place	Geographical location		Date	Locality No.
Rupert House	78° 27′ W	51° 45′ N	7th July	1
Boatswain Bay	78° 56′ W	51° 49′ N	8.	2
Island near Loon Pt	78° 45′ W	52° 08′ N	8—9.	3
Governor's Island, N of Eastmain	78° 35′ W	52° 17′ N	9—10.	4
Island near Long Pt (Moar Bay)	78° 55′ W	52° 45′ N	10—11.	5
Paint Hills	79° 00′ W	53° 02′ N	11.	6
Island near Black Whale Island	78° 58′ W	53° 21′ N	11—12.	7
Island N. of the mouth of Beaver River	79° 05′ W	53° 27′ N	12 13.	8
Island near Walrus Pt	79° 10′ W	53° 42′ N	13.	—
Fort George	79° 01′ W	53° 50′ N	13—19.	9
George River excursion			15.	
Island in Goose Bay	79° 08′ W	53° 55′ N	19.	10
Island N. of Piagochiwi River	79° 12′ W	54° 09′ N	19—20.	11
Island S. of Attikuan Pt ..	79° 25′ W	54° 12′ N	20.	12
Island near Attikuan Pt ..	79° 30′ W	54° 17′ N	20—21.	13
Island S. of Salmon River ..	79° 40′ W	54° 34′ N	21—23.	14
Cape Jones	79° 50′ W	54° 37′ N	23—24.	15
Cape Jones, a few miles NE ..	79° 48′ W	54° 38′ N	24—25.	16
Limestone island in Long Island Sound	79° 32′ W	54° 45′ N	25—27.	17
Mainland coast of Long Island Sound	79° 02′ W	54° 50′ N	27.	18
Near Sucker Creek mouth ..	78° 35′ W	54° 58′ N	27—28.	19
Black Whale harbour	78° 08′ W	55° 09′ N	28—29.	20
Great Whale River	77° 44′ W	55° 17′ N	29th July-26th August	21

this area. Phenologically expressed, the difference between the maritime zone and inland is at least 1—2 weeks, i.e. judging from the elongation time of the spruce shoots, the spring comes to the mainland coast 1—2 weeks earlier than to the archipelago outside the coast line. Also, the area extends in a S-N direction about 300 miles, which causes great phenological differences between various points.

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[1] Geographical locations and place names according to Mr. W. K. W. Baldwin.

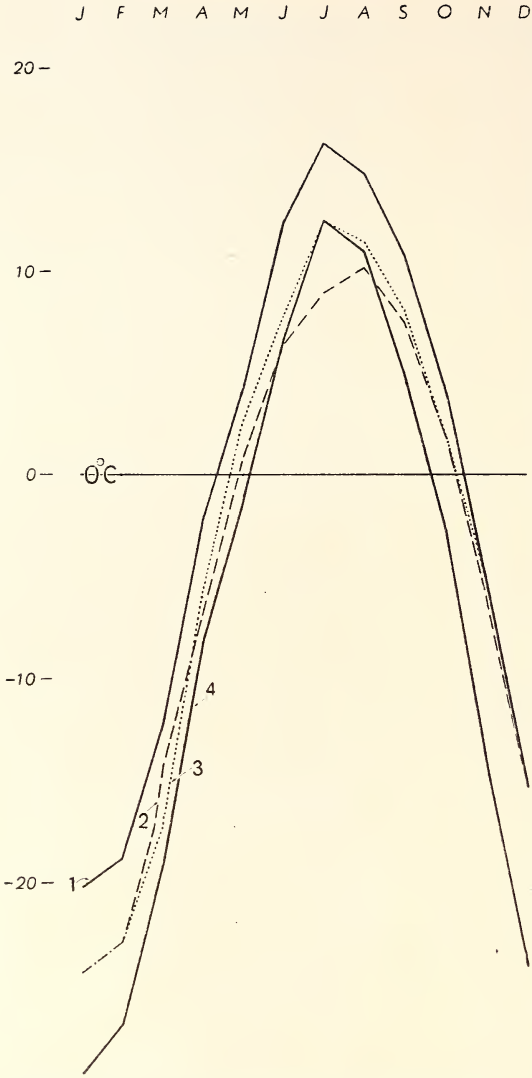


Diagram 1. Monthly mean temperatures at four stations around Hudson Bay: Moosonee (1), Fort George (3), Great Whale River (2) and Fort Churchill (4). Numbers according to Connor 1938.

Several plant collectors have visited the coast, but collections have, owing to transport difficulties, mainly been made at or near the HBC-stations along the coast, i.e. Rupert House, Eastmain, Old Factory, Fort George and Great Whale River. The collection of vascular plants made during our expedition has been listed by Mr. W. K. W. Baldwin (a large MS in the National Museum of Canada Herbarium). Including other collections, particularly Potter's list of 1934, the number of species of vascular plants occurring on the coast land from Moose River to Great Whale River amounts to nearly 800.

The flora on the east coast of James Bay and Hudson Bay seem to be richer than the flora on the Atlantic coast of the Labrador Peninsula. This is partly due to the rich amount of glacial till of less acid origin. A more or less clear arctic element in the flora appears as much to the south as on the islands off Eastmain.

The commonest vascular plants occurring in the forest (or only occasionally growing in the forest patches near the maritime treeline) are listed in Table II (i.e. the vascular plants on the sample plots described in Chapter 4).

The zonation of the vegetation on the islands is, from the sea shore upwards, generally the following:

1. *Fucus*-girdle or a saline *Carex* meadow.
2. Sandy soil with *Honckenya peploides* and/or *Lathyrus japonicus.*
3. Dry meadow with *Elymus arenarius* var. *villosus, Hierochloë odorata, Festuca rubra* var., etc.
4. Arctic-maritime heath with *Empetrum hermaphroditum, Vaccinium vitis-idaea* ssp. *minus, V. uliginosum, Arctostaphylos alpina;* on less acid soil including large patches of more or less »calciphile» arctic plants: *Dryas integrifolia, Saxifraga tricuspidata, Astragalus alpinus, Pyrola grandiflora* etc.
5. Towards the »inland» from the arctic heath (usually a boulder, gravel or sand ridge forming a raised beach some 15—20 feet above sea level), the first spruces appear scattered on a dry plain — if the island is big enough. There is also often a turfy tundra with *Empetrum, Vaccinium vitis-idaea, Rubus chamaemorus, Carex* ssp., surrounding fresh-water ponds with *Hippuris tetraphylla, Myriophyllum exalbescens* etc.

For general data concerning the forest conditions in this part of the Labrador Peninsula, see HALLIDAY (1937), VILLENEUVE (1946) and H 1949[1]. From the clay belt with its rich white spruce and balsam fir forests the area stretches up to the southern border of the forest-tundra. The maritime tree-line is marked on Map 1, which also shows the places mentioned in the itinerary in Table I.

2. The Tree and Bush species in the Area.

In the area the following tree species occur: white spruce, *Picea glauca* (Moench) Voss, black spruce, *Picea mariana* (Mill.) B.S.P., balsam fir, *Abies balsamea* (L.) Mill., tamarack, *Larix laricina* (DuRoi) K. Koch, jack pine *Pinus Banksiana* Lamb., white birch, *Betula papyrifera* Marsh. coll., balsam poplar, *Populus balsamifera* L. and aspen. *Populus tremuloides* Michx. Cedar, *Thuja occidentalis* L., occurs near Rupert House, according to BELL 1879. Regarding the general distribution of these species, compare maps in H 1949. Thus, all the tree species of the Labrador taiga occur in the eastern coastal section of James Bay.

White spruce.

This spruce species is the commonest tree near the coast and on the islands; *it forms the maritime tree-line in the area.* Its dominance in the coastal plains

[1] The expressions H 1949, H 1948 etc., refer to the author's papers; see p. 82.

and in the river valleys is largely due to the clayey or sandy soil of the marine deposits in the area, as already pointed out by Low 1897, see also Dutilly and Lepage 1948. White spruce shows, thus, in the coast zone about the same edaphic requirements as does balsam fir and balsam poplar S and E of James Bay.

On exposed habitats the white spruce needles are short, 5—8 mm only. The growth in length of the annual shoots appears from the following (mean values of 11 branches): 1946 2.8 cm, 1945 3.6 cm, 1944 3.1 cm, 1943 3.6 cm, 1942 2.7 cm, 1941 2.8 cm, 1940 2.6 cm and in 1939 3.9 cm. Thus, 1940 and 1946 appear as minimum years in growth of length of branches on white spruce at the maritime tree-line.

In the maritime border-zone the height of white spruce seldom exceeds 30—36 feet. But the trees generally grow fast; the annual radial growth on many habitats is 2—3 mm in good years, compare Table XI. The good growth in thickness is probably caused by the wind, which improves the cambial activity of solitary trees on exposed habitats, compare Büsgen-Münch 1927 (p. 165—166).

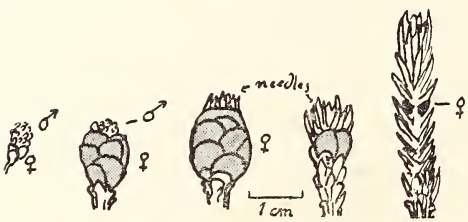


Fig. 5. Deformed white spruce cones and male inflorescences from sample plot 11, an exposed maritime forest.

The oldest white spruce seen at or near the maritime tree-line was at least 400 years (rotten in the centre). In general, however, the white spruce trees were fairly young. Sometimes one had *the impression that the white spruce forest is advancing towards the sea.*

The white spruce had a rich cone year at the coast in 1947 (1-year-cones). For instance, one 75 year old white spruce (24 feet, 7 inches DBH) on George Island had at least 1,500 cones. Cone formation was noted on very exposed localities, showing that the »vegetative» tree-line in this area coincides with the »generative» tree-line. The cones were usually 3 cm long. On very exposed localities the white spruce cones, however, were only 1.5—2 cm long, i.e. the normal size of black spruce cones. Near the sample plot 11, some teralogically interesting white spruce cones were collected, see Fig. 5.

Seed years occur fairly often in this area, also at or very near the maritime tree-line. The development of the seedlings was, however, often poor; the white spruce seedlings were of the bushy type often seen on lichen heaths, depressed or damaged by wind or snow. 71 seedlings were microscopically examined:

Age in 1947	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Number of wspr seedlings	—	2	—	—	—	1	1	4	1	3	3	3	5	2	6	3	5	2
Age in 1947	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Number of seedlings	4	5	2	2	2	2	—	—	2	2	—	—	—	2	—	—	2	1

4 older seedlings were found to be 42, 42, 43 and 45 years old. For details regarding the reproduction in the area, compare the description of the sample plots below.

Some phenological notes: The development of the white spruce is, of course, much delayed near the maritime tree-line. On the localities 3—8, i.e. the islands outside Eastmain and Fort George, the shoots of white spruce were still more or less in bud-stage, see Fig. 6, with 2—4 mm long needles. At Fort George, 14—15th July, the elongation of the annual shoots was nearly finished. Increment cores from sample plots 9, 10, 13, 13a showed that until the 12th of July only 2—3 cell layers were irregularly developed. Thus, on the islands, the cambial activity begins as late as in the first days in July. The pollination of white spruce occurred 11—12 July on locality No. 7; the pollination of white spruce was just finished on the 27th July on locality No. 18.

White spruce, partly as low bushes only, was seen on the localities 1—13, 18—21. According to information received from Mr W. K. W. Baldwin (letter Jan. 31, 1950) white spruce, about 5 feet high grows on a high rocky Precambrian island in the Solomons Temple Islands,

Fig. 6. White spruce twig from island N of the mouth of Beaver River, locality 8; July 12th 1947.

Fig. 7. Black spruce twig from island near Black Whale Island, locality 7; July 11th 1947.

see Map 1. He also saw 8 feet high white spruce on South Twin Island, a few clumps on the east side of the island, on »low, sheltered land». No white spruce was seen on Gasket Shoal or Bear Island.

Black Spruce.

Black spruce dominates the Labrador taiga, outside the areas with marine deposits. In the eastern coastal zone of James Bay and Hudson Bay, black spruce, however, is less common than white spruce. This can clearly be seen in the notes from the places visited. Black spruce was noted, partly as low, creeping bushes only, on the localities 1, 6—9, 11, 20 and 21. GARDNER (1946) reports black spruce from Beacons Island outside Fort George and from Bill of Portland Island. Interesting information was given to the author by Mr. W. K. W. BALDWIN after his trip in 1949 when he visited several of the outermost islands. On a highrocky Precambrian island in the Solomons Temple Islands he found dwarfed black spruce, though only two clumps, about 1 ft. high; on South Twin Island white spruce was seen but not black spruce, see above.

One of the reasons for the relative scarceness of black spruce at or near the maritime tree-line is the bedrock; black spruce seems to prefer more acid soil, whereas the glacial till of sedimentary bedrock origin on the islands is more favourable for white spruce, as are also the marine deposits on the coast. East of the plains of James Bay, black spruce, according to LOW's reports, entirely dominates the taiga.

Black spruce often forms creeping carpets or thickets and its branches root easily; the easy formation of adventitious roo s in black spruce is a well-known feature of this species. On exposed localities at the maritime tree-line black spruce occurs only as creeping low bushes, while white spruce still raises

its rugged stems against the wind. At Black Whale Harbour black spruce was seen growing on limestone, which is fairly unusual, at least according to the author's experience.

The growth in length of the annual shoots of black spruce on exposed maritime localities (on the islands) appears from the following small sample (mean value of 6 branches only): growth of the annual shoot in 1946 3.1 cm, 1945 3.8 cm, 1944 3.5 cm, 1943 3.4 cm, 1942 3.2 cm, 1941 2.9 cm, 1940 2.6 cm, 1939 2.9 cm. Thus, 1940 and 1946 are minimum years in growth in length also for black spruce.

The cone formation of black spruce at or near the maritime tree-line was not prominent. The following small sample shows the age, microscopically determined, of some black spruce seedlings collected near Fort George:

Age in 1947	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Number of seedlings	2	1	—	1	2	—	4	1	4	—	2	2	—	1	2	—	1	2

It must be pointed out that such determinations of the age of seedlings are very approximate. The samples show, however, that there have been several seed years of white spruce and black spruce in the area in the last decades.

Some phenological notes on the development of black spruce showed, as regards the growth of the annual shoots and needles, similarities to those on white spruce: 11th of July the elongation of the annual shoots of black spruce had begun at the maritime tree-line, see Fig. 7. 14th of July at Fort George the elongation of the annual shoots of black spruce was more or less finished.

Tamarack.

Tamarack is not common on or near the maritime tree-line in this area. On the Atlantic coast of the Labrador Peninsula, see the author's paper 1939, tamarack sometimes forms its own peculiar zone on the coast mountains, whereas tamarack on the east coast of the Hudson Bay stays away from the shore. Only at Loons Island and at Black Whale Harbour some low tamaracks were seen near the maritime tree-line. G. GARDNER (comm. by letter) reports tamarack from Beacons Island outside Fort George. POTTER mentions (1934) tamarack from Mt Sherrick (near Boatswain Bay, see Table I) and Charlton Island.

The tamaracks near the maritime tree-line showed rich cone formation. At Black Whale Harbour tamarack grows nearer to the shore than black spruce (probably because of the limestone). Some tamarack seedlings collected at Fort George were approximately 8, 11, 11, 12, 14, 14, 28 and 43 years old. — On July 9th the tamaracks on Loons Island had their needles developed, 1—1.8 cm long.

Fig. 8. Jack pine heath about 12 miles inland from Fort George, on a large island in George River; compare sample plots 3 and 4. Photo E. H. Kranck.

Balsam Fir.

Balsam fir is common near Rupert House, where it reaches timber size. It was, however, not observed on the islands during the journey to Fort George. There, one balsam fir bush (2 feet high, 2 inches in diameter, 55—60 years old) was seen on the SW part of George Island, but not elsewhere. Balsam fir was not seen at the coast N of Fort George. It occurs, however, inland according to Low's reports. Its distribution seems to be at least partly restricted by the inland limit of the marine deposits with their rich alluvial soil. Low reports (1900, see p. 160 in »Extracts») balsam fir from islands in Richmond Gulf; he also mentions balsam fir from the upper George River.

On both localities where balsam fir was observed, it showed strong vegetative propagation; at Rupert House also good generative reproduction.

Balsam fir clearly avoids the maritime zone. This is not the case on the Atlantic coast of the Peninsula, see H 1939.

Jack Pine.

Pine occurs on Mt Sherrick (near Boatswain Bay, see Table I), according to POTTER (1934). This is probably its only locality near the maritime treeline. The author saw jack pine on an island in George River, about 12 miles up the river from the HBC. There it occurred on a burned lichen heath, see sample plots 3 and 4 below and Fig. 8. The pines grow fast there, reaching in about 25 years a height of 18—21 feet, with an annual radial growth of 3—5 mm in good years. The annual growth in length of 5 branches was: 1946 14 cm, 1945 15 cm, 1944 19 cm, 1943 18 cm, 1942 22 cm and 1941 20 cm, thus a good annual growth in length of old branches.

LOW reports (1889) jack pine from the area between Roggan River and George River.

In this area, at least, jack pine seems to avoid sedimentary bedrock and marine deposits of clayey soil, compare FERNALD (1919) and RAYMOND (1950). Note the description by DUTILLY and LEPAGE (1948).

White Birch.

White birch is not common in the coastal area. POTTER (1934) reports *Betula papyrifera* var. *cordifolia* from Mt. Sherrick. G. GARDNER (comm. by letter) collected white birch at Fort George. Fragments of white birch bark were seen on the shores of the islands as far north as Cape Jones. LOW (1896) reports white birch from the interior, but never, however, occurring frequently.

The author collected »small white birch», i.e. *Betula occidentalis* Hook. (det. A. E. PORSILD) from Loons Island.

Balsam Poplar.

This tree was seen at Ruperts House, Loons Island (fruct.), George Island, George River (fruct.) and Great Whale River (see p. 45). Along George River balsam poplar reaches about 30 feet in height and 16 inches DBH. Regarding balsam poplar on Loons Island, compare sample plots 9 and 10 below. The distribution of balsam poplar is, according to LOW (1897), largely restricted inland by the eastern limit of the marine deposits. POTTER mentions balsam poplar from Eastmain and Charlton Island (1934), LOW (1900) from islands in Richmond Gulf.

Aspen.

Aspen was seen on our journey only on Loons Island (some low bushes) and at George River 12 miles inland from the HBC post on the jack pine locality. There aspen reached about 27 feet in height and 3 inches DBH.

Notes regarding this species are scarce in the literature from this coast. POTTER observed aspen on Charlton Island (1934) and A. E. PORSILD collected it on Akimiski Island (Nat. Mus. Herb. Ottawa). BELL's map of 1895 shows the northern limit of aspen stretching as far north as to Little Whale River. This is probably a mistake. LOW (1897) mentions aspen from the neighbourhood of Cape Jones and from the portage-route between Lower and Upper George River.

The Bush Species.

The commonest bush species at the maritime tree-line is the glandular dwarf birch, *Betula glandulosa* Michx., which was noted on the localities 3, 6, 8—13, 16—21. *Betula pumila* L. was not met with in the area covered. Glandular dwarf birch goes out to the outermost (large) islands in the Hudson Bay and James Bay. It is collected on South Twin Island (F. JOHANNSEN, Nat. Mus. Herb. Ottawa) and on Belcher Islands (see RAUP 1947).

The alder, *Alnus crispa* (Ait.) Pursh., goes out to the maritime tree-line and forms large girdles which give shelter for the white spruces (sometimes, however, white spruce shelters the alder thickets). In the localities 12 and 13 white spruce was seen, but not alder. Towards the north, however, alder goes a little farther north than spruce; alder is found near Cape Chidley, north of the spruce limit (RAUP 1947). On the east coast of Hudson Bay, alder grows at the mouth of the Nastapoka River (MANNING 1946); the spruce limit is fairly near here, some 10—20 miles inland (l.c.). Alder and white spruce seem, in general, to grow well together.

The speckled alder, *Alnus rugosa* (DuRoi) Spreng. var. *americana* (Regel) Fern., does not occur at the maritime tree-line. It was found at Rupert House, Fort George, along George River and along Great Whale River during our excursions in 1947.

The *willows* were represented by many species. The commonest species on the islands and along the coast were *Salix cordifolia* Pursh. var. *callicarpaea* (Trautv.) Fern., *S. reticulata* L. and *S. vestita* Pursh., all of which seem to prefer less acid soil. *Salix glauca* coll., *S. planifolia* Pursh. and *S. pedicellaris* Pursh. var. *hypoglauca* Fern. were fairly common species in the forests. Regarding the distribution of the willows in the area, compare RAUP 1943 and BALDWIN's above mentioned list in Nat. Mus. Herb. in Ottawa.

The juniper, *Juniperus communis* L. (mostly var. *depressa* Pursh.) was seen on the localities 2, 3, 9, 10, 18—21. Thus, this species goes out to the maritime tree-line. Other similar localities: Mouth of Nastapoka River (MANNING 1946), Gasket Shoal (BALDWIN, comm. by letter), South Twin Island

(F. JOHANNSEN, Nat. Mus. Herb. Ottawa). — *Juniperus horizontalis* Moench. is not reported from the east coast of Hudson Bay or James Bay, except from Rupert River, see DUTILLY and LEPAGE (1948).

The other bush species are of minor importance. Mountain ash, *Sorbus americana* Marsh, was seen only at Boatswain Bay and at Great Whale River; it is also collected from Charlton Island (A. E. PORSILD, Nat. Mus. Herb. Ottawa), Mt. Sherrick and Eastmain (POTTER 1934). *Ribes triste* Pall. var. *albinervium* (Michx.) Fern. was found on the localities 9, 18 and 21, *R. glandulosum* Grauer on 9, 10 and 21, and *R. oxyacanthoides* L. on 3, 6, 9 and 13. *Shepherdia canadensis* (L.) Nutt. was extremely common (3, 6, 10—13, 15—18, 20, 21). *Myrica gale* L. was seen on the localities 2, 9, 10, 19 and 20. *Cornus stolonifera* Michx. was seen at George River, *Viburnum edule* (Michx.) Raf. at Fort George and Great Whale River and *Amelanchier Bartramiana* (Tausch.) Roemer at the same places. *Prunus pennsylvanica* L. was not seen on our journey; POTTER (1943) reports it from Eastmain and LOW (1889) from the latitude 54° N (about Piagochiwi River). *Rosa acicularis* Lindl. was seen at Loons Island. Thus, the absolute maritime tree-line is reached only by a few of the common bush species in the forest region around James Bay.

3. The Maritime Tree-line.

The maritime tree-line in the area is approximately marked on Map 1. The expression maritime tree-line means here the outermost limit for coniferous tree-species, of whatsoever size the individuals are, low bushes or trees. Some times, therefore, low creeping spruce bush marks the maritime tree-line. The northernmost point where the tree species goes down to the coast line is a point just S of the entrance to Richmond Gulf, compare GARDNER and WILMOT 1943. From there the maritime tree-line almost coincides with the coast line. On the east side of the islands west of Manitounuk Sound there are forest patches, as could be seen on our flight from Great Whale River to Port Harrison, see below. The forest avoids the exposed Cape Jones country; locality 18 is near the place where the maritime tree-line turns inland from the cape. The tree-line reaches the coast again somewhere between the Salmon River and the Seal River and from there to the south the mainland coast is well forested. The tree-line goes out to the islands as can be seen from the short notes on the places visited, see below.

The maritime tree-line is, as already mentioned, usually formed by the white spruce on this coast of the Labrador Peninsula. Creeping black spruce

Fig. 9. View of the white spruce forest patch on island near Loon Pt.; locality 3. Photo W. K. W. Baldwin.

can be seen on some of the islands. Where the two spruce species occur together on exposed localities, white spruce still attains the shape of a rugged tree whereas black spruce forms only creeping bushes. The same ecological difference between the two species can be seen on mountain slopes in the interior, compare my Knob Lake report (1950). A reason for the dominance of white spruce is probably the sedimentary bedrock on the islands and the wide areas of marine deposits along the coast. White spruce seems to prefer less acid soil than black spruce.

The other tree species in the area, see Chapter 2, avoid the maritime tree-line. Only sporadically tamarack, balsam poplar or aspen can be seen on the islands. The coastal zone is also avoided by balsam fir, jack pine and white birch.

Compared with the Atlantic coast of the peninsula, the differences are obvious. On the Atlantic coast, for instance, balsam fir goes out to the sea shore on several places (H 1939) and black spruce seems to be as common as white spruce in the coastal zone.

Regarding the shape of the trees at the maritime tree-line, see above. Such strongly wind-deformed thickets as those seen on the south-eastern shore of Labrador or on Newfoundland can not be seen on this coast. Snow damaged trees are usual on the maritime tree-line.

On most of the islands with suitable shores *driftwood* was found plentifully.

Because of the fact that the islands visited during the journey were fairly near the coast the occurrence of driftwood is quite natural. Owing to the stream circulation in the Hudson Bay driftwood is also found on the islands far out in the bay. MANNING made 1947 some interesting notes: driftwood »of all ages and sizes to trees 2 or more feet in diameter lined the southern shore of Driftwood Island» (1947, p. 63). Driftwood was seen also on Kidney Island (Sleepers Islands), Marcopeet, Farmer and Ottawa Islands. No driftwood was seen on the eastern mainland coast. GARDNER and WILMOT reported (1943) driftwood from Sleepers Island, »large stumps on the beaches». Notes on driftwood in Hudson Bay are of hydrographic interest.

In the following the places visited during our journey in 1947 are presented including some facts regarding the maritime tree-line (regarding their geographical location, see Table I):

1. *Rupert House.* A short excursion in the surroundings only, compare sample plots 16 and 22; see DUTILLY and LEPAGE (1948).

2. *Boatswain Bay.* A short stop at a sandy beach with surrounding granite-pegmatite cliffs with scattered forest patches of white spruce reaching about 24 feet in height, sheltered by alder bush. In the neighbourhood Mr Sherrick; regarding its vegetation, see POTTER (1934).

3. *Island near Loon Pt* (= Loon Island in the following). A skerry (about ½ sq. mile) with an arctic-maritime heath between cliffs of granite, high enough to shelter forest patches of white spruce reaching 36 feet in height. Scattered tamaracks and balsam poplars grow here, as also some aspen bush. See Fig. 9 and sample plots 9 and 10.

4. *Governor's Island.* »Much used Indian camping site with old burnt stumps in sandy soil» according to BALDWIN's notes. Low rugged forest patches of white spruce noted here.

5. *Island near Long Pt,* Moar Bay. A low skerry with plenty of driftwood, and as it seems, also remains of an earlier larger spruce »forest». A few low white spruce bushes and four white spruce seedlings, 1—2 feet high. Several arctic and calciphile elements occur in the flora.

6. *An island in the Paint Hills'* archipelago. Of the same size as Loon Island, with, however, more arctic elements in the flora. The bedrock is unusual syenite, according to Dr E. H. KRANCK. Scattered white spruce, reaching 24 feet in height on a more or less open arctic-maritime heath. Black spruce forms creeping carpets only, several sq. metre wide but ½—1 feet high only. Very few cones noted on white spruce, but some white spruce seedlings, 1—1 ½ feet high, noted.

7. *Island near Black Whale Island.* Scattered tree-sized white spruces and creeping black spruce. The vegetation of the same character as on the localities 5 and 6, i.e. with several arctic species in the heath vegetation.

8. *Island N of the mouth of Beaver River.* Several small patches of white spruce forest. In one of the stands (here alder in shelter of white spruce) 15 trees, reaching 24 feet in height, one of the trees 24 feet high, 4 inches DBH, 100

years old, few cones; another tree, strongly deformed by wind and snow, 6 feet high, 7 inches DBH, 120 years old, rich cone formation, in pollination. Also »candelabrum»-formed white spruce was seen here. The close affinity between white spruce and alder is evident. The trees are mostly badly damaged by wind and snow. Several black spruce thickets and carpets seen on the island. A few white spruce seedlings and one black spruce seedling noted, see sample plots 13 and 15. See Fig. 2.

9. Fort George. This place has often been visited by collectors. Regarding its forest-botanical conditions, see Fig. 1 and sample plots 3—8, 15, 18, 19, 23 and 24. The author did not see bigger trees than white spruces 54 feet high and 16 inches DBH. Bell reported (1879) that logs 2 feet in diameter were floated down the river, see also Gardner and Wilmot (1943).

10. Island in Goose Bay, about 6 miles from Fort George. Only white spruce seen here, growing in patches between granite cliffs. Near this larger island (whence sample plot 14) a granite island with boulder ridges and low white spruces forming the maritime tree-line, together with the usual alder girdle.

11. Island N of the mouth of Piagochiwi River. Low granite island with fresh-water ponds and sandy soil. Scattered white spruce trees and black spruce bushes, 10—15 sq. metre wide, with cones 1 ½ feet above the ground. Also a black spruce seedling seen among a few white spruce seedlings.

12. Island S of Attikuan Pt. A typical low skerry with many boulders, several hectares wide. Only two white spruce bushes seen; one half dead, 1 ½ feet high, no cones, the other 4 feet high, 6 sq. metre wide, few cones (of the same size as normal black spruce cones) and rooting branches, a feature unusual with white spruce.

13. Island near Attikuan Pt. A low sandy island, 24—30 feet high, with boulders and arctic heaths. Scattered white spruce bushes, one of the biggest 1 ½ feet high and 30 sq. metre wide, with rooting branches, see above, no cones, partly frost damaged; another white spruce bush, 3 feet high, 9 sq. metre wide, had no cones. There were 10—15 such bushes in the central part of the island, however, at least 600 feet from the shore. For the first time during the journey, small »palsa» bogs were seen here, on the turfy tundra patches behind the boulder ridges, with 1 ½—3 feet high tussocks (i.e. »palsas», compare Wenner 1948 and the author 1939). No black spruce and no alder.

14. Island S of the mouth of Salmon River. A large, low island (24—30 feet only), an old »drumlin», some hectares wide. Freshwater ponds on gravel ridges. No spruce, no alder and no dwarf birch.

15. Cape Jones. Granite cliffs, real saltwater plants and large arctic tundra plains inland from the cape. An interesting »calciphile» flora grows on the localities 15, 17. The first trees appear about 15 miles inland, according to some Indians met at the cape.

16. Small point 2—3 miles E from Cape Jones. Forced to land here in storm. A typical arctic cliff shore, tundra landscape with arctic heaths and tundra bogs with 3—4 feet high »palsas». No alder or spruce was seen on an excursion 2 miles inland.

17. Island in Long Island Sound. Precambrian limestone cliffs, partly quart-

Fig. 10. The maritime tree-line at »Little Cape Jones». White spruce; note the creeping carpet against the sea shore. See the description of sample plot 11 and locality 18. Photo E.H. Kranck.

site, about ½ sq.miles only, forced to land here in storm. No trees; a calciphile arctic vegetation, rich in species. On the mainland coast opposite this island a large tundra landscape. No trees met with during an excursion about 2 miles inland. No alder, but some scattered dwarf birch.

18. Mainland coast of Long Island Sound (not the same part of the shore as mentioned above, see geogr. location in Table I). Here one of the first forest patches seen N of Cape Jones. The forest comes down between granite cliffs on terraces 30—45 feet above sea level. Fig. 10 shows a typical maritime tree-line in the area with some white spruce seedlings, a low white spruce carpet and low ragged white spruce stems. About 40 % of the trees in the forest patches are dead. The white spruce (no black spruce seen here) reaches 30 feet in height and 10 inches DBH. Arctic-maritime flora elements intermingle with common silvine elements in the ground vegetation in the forest patches on the coast.

19. Sucker Creek (near the mouth of the creek). A sandy area with old, but also »new» sand dunes. White spruce lichen forests grow on the old dunes and on the sand terraces, compare sample plot 1. Such forests are common along the coast northwards. On the slopes of the old dunes grow white spruce (no black spruce seen here) feather moss forests and in the depressions white spruce »muskegs». Arctic-maritime elements intermingle in the ground vegetation in the coast forest. ½—1 mile from the coast inland good pulpwood-sized forest.

Young white spruce seedlings are frequently seen. »Candelabrum»-formed white spruce noted here. The sample plots 1,20 and 21 are from Sucker Creek.

20. Black Whale Harbour (a part of the coast about 1 mile S from the harbour place). Limestone bedrock, old sand dunes and terraces. A little inland from the shore granite cliffs. On the limestone grows white spruce, also some seedlings found near the outermost trees. On turfy habitats, about ½ mile inland from the white spruce outposts, the first tamaracks occur: the biggest is 9 feet high and badly wind-deformed (rich cone formation, 153—160 years old); around the trees some old seedlings occur. The white spruce forms some typical »candelabrum»-trees on the limestone cliffs about 45 feet above sea level. Sample plot 12 seems to be typical for these coast forests. About 1—1 ½ mile inland the first black spruce bush were met with on limestone bedrock, in *Salix reticulata*-vegetation, 1—5 feet high bushes, badly grown. Fairly good forest (white spruce) 1 ½ mile inland, reaching about 33 feet in height and 14 inches DBH. Compare sample plots 12 and 17.

A flight from Great Whale River to Port Harrison was undertaken on August 11th 1947 and from Great Whale River to Moose River on August 26th. During these flights the forest limit and tree-line conditions could be studied to some extent. The forest reaches more or less all the way to the shore northwards to the entrance of Richmond Gulf. On old dunes and glacifluviale terraces spruce lichen forest dominated. Forest patches (probably all white spruce) occur in the sheltered valleys on the steep east shores of the islands in Manitounuk Sound. Spruce forest patches can also be seen on Castle Peninsula and on the western shores of Richmond Gulf. The valleys around the North River seem to be richly wooded, but just N of it the spruce forest patches seem to be very scarce. The big islands in the Gulf are partly wooded. The barren ground covers at least 50 % of the country E of the Gulf. The seemingly good forest around the shores and in the northern end of the Gulf is probably due to the sedimentary bedrock here; just E of the Gulf the large granite shield begins. The sea shore is treeless from the Gulf Hazard northwards. Some scattered patches of spruce were seen in the Sheldrake River valley (?) and during our flight an uncertain note was made of spruces in the Nastapoka River valley near the shore. According to MANNING (1946) there are some spruce forest patches 10—20 miles from the mouth of the Nastapoka River. The rolling barren country N of Richmond Gulf is poor in soil.

Regarding the polar limit of trees in this part of the Peninsula, compare BELL (1879, 1895), MANNING's pictures of the country around Lake Minto and Bush Lake (1947) and MARR's description of the Richmond Gulf area, including good pictures of the area (1948). GARDNER and WILMOT (1943) state that »according to local authorities the real forest begins 40—50 miles inland from the post (= Port Harrison)» (?).

4. Sample Plots, 1—24.

In Table II the ground vegetation, including the bush species, of 22 sample plots and a list of plants growing in a bog (No. 23) and in a balsam grove (No. 24) appears in concentrated form. The sample plots are shortly described below, including notes on the trees and their age, the cryptogam cover and the reproduction of the trees. The sample plot are, unless otherwise stated, about 1/40 acre, i.e. 10 M. × 10 M. The ground vegetation analysis, an ocular estimation only, was made on a typical part of the sample plot, about 6 feet × 6 feet. The frequence scale is the following: 3 = dominant, 2 = common, 1 = scattered, × = occasional individuals of a species.

The sample plots are in the text below and in Table II arranged approximately according to the general character of the habitat and forest type. The driest and poorest forest types begin the series. This »unscientific» and unconventional method gives, however, some idea of the affinity of the commonest forest vascular plants to each other.

Abbreviations: wspr = white spruce, bspr = black spruce. The expression »30 × 6, age 80, at the ground 90» means a tree 30 feet high, 6 inches in diameter 4 feet above the ground, 80 years old 4 feet above the ground and 90 years old at the ground, according to increment borings. Many of these trees are included in Table IV and are marked with italics. The expression »12 × 16 y» means a seedling, 12 inches high and 16 years old. The age was microscopically determined. The annual rings of the increment cores were counted using a microscope of special construction; see Chapter 9 regarding the measurements of the growth in thickness. Owing to the depressed growth of the seedlings on exposed localities, the age determinations are approximate only.

One sample plot (No. 2) is from Great Whale River, see p. 46. It has been included in Table II because of its situation on the maritime tree-line.

1. *Sucker Creek.* Rolling terrain of dunes, partly old, partly new, near the mouth of Sucker Creek, about ½ mile from the sea shore. On the sample plot wspr on lichen heath, the trees are partly of »candelabrum» habitus; compare H 1949 and p. 40 below. Rich formation of cones, here unusually long (5—6 cm). Trees on the plot: *30 × 6*, age 120 at the ground, 18 × 3, age 45—50, *27 × 5*, age 90—95, 7 × 2, age 55 at the ground, 6 × 1 ½, age 45—50 at the ground.

Cryptogams: 3—5 inches thick *Cladina alpestris*-dominated lichen cover, incl. *C. mitis, C. rangiferina, Cetraria nivalis, Stereocaulon alpinum, Cladonia amaurocraea, C. gracilis, C. coccifera* and *Dicranum fuscescens*. The (dry) lichen cover forms »flakes» of about 1 × 1 or 1 ½ × 1 ½ feet. In this type of forest seeds of vascular plants usually germinate in the furrows between the flakes. Under the

trees *Hylocomium splendens,* as also *Empetrum hermaphroditum* and *Vaccinium vitis-idaea.*

Reproduction: 4 wspr seedlings, 10 × 36 y, 8 × 28 y, 4 × 23 y and 9 × 18 y of the depressed bushy type of seedlings usually found on lichen heaths in the north.

2. *Great Whale River,* see p. 46 below. The sample plot is included in Table II.

3. *George River,* 12 miles from Fort George. Large sandy island in the river with a burnt heath, now covered with jack pine lichen forest. The trees are low, mostly 18—21 feet. The area was burnt 25—30 years ago. The humus layer under the lichen cover is about 1 cm thick. The trees are long (6—9 feet) and low branched, see Fig. 8. Bspr comes in under the pines. Bspr is here only 3—4 feet high but of about the same age as the pines. The size and age of the pines on the sample plot: 21 × 5, age 17, 18 × 4, age 17, 24—25 at the ground, 15 × 4, age 16, 10 × 1 ½, age 19—20. In the neighbourhood aspen trees grow well among the pines and bspr.

The annual growth in thickness (in 0.01 mm) of the three bigger pine trees mentioned above (series a):

	1946	1945	1944	1943	1942	1941	1940	1939	1938	1937	1936	1935	1934	1933
a)	146	169	155	164	215	199	196	234	330	342	301	394	306	309
b)	235	229	206	261	260	276	272	228	298	318	305	388	270	308

Series b includes the two pines mentioned in sample plot 4. Note that the growth in thickness is good, considering the very northern situation of the sample plot.

Cryptogams: dominant *Cladina mitis* and scattered *Cladonia crispata* incl. some barren patches. The lichen cover is very thin, 1 inch only, showing the usual slow regrowth of a lichen heath, here even 1 inch only in 25—30 years.

Reproduction: On the sample plot no pine or spruce seedlings. The cone production was satisfactory. The flowering was just finished on the 15th of July (female inflorescences »closed»). In the neighbourhood on a similar habitat 4 pine seedlings: 4 × 7—8 y 10 × 7 y, and two others, 12—13 and 15 years respectively. Some bspr seedlings nearby were 6 × 19 y, 6 × 18 y and 19, 21 and 22 years respectively, thus showing a slow growth compared with the pines.

4. *A similar sample plot* No. 3, about 100 feet from the above mentioned. Here some alder (*Alnus crispa*), richly fructif., among the pines. The pines on the sample plot: 18 × 4, age 16, 24 at the ground 21 × 4 ½, age 17—18, about 20 at the ground. A low bspr on the sample plot, 4 × 1, age 15—20 years at the ground.

Cryptogams: dominant *Cladina mitis,* with frequent barren patches.

Reproduction: no pine or bspr seedlings on the sample plot itself.

5. *George Island,* S-side, bspr dwarf shrub lichen forest. The humus layer under the lichen cover about 1 inch thick. The bspr about 25 × 5 in average. Nearby wspr and tamaracks on lichen heath. Some bspr trees: *24 × 5,* age 65, *27 × 6,* age 100 (rich male flowering), *18 × 4,* age 56, 8 × 2, age 70 at the ground (few cones).

Cryptogams: dominant *Cladina alpestris,* scattered *C. mitis* f., *C. rangiferina* and *Stereocaulon* cfr *paschale.* The lichen cover 3—4 inches thick. Epiphyte lichens on bspr: *Alectoria jubata, A. simplicior, Parmelia physodes, P. sulcata, Cetraria ciliaris, C. pinastri.*

Reproduction: Generally good cone production. No bspr seedlings on the sample plot. Nearby two wspr seedlings of the bushy type: 5 × 12—13 y and 3 × 15 y.

6. George Island, the inner part of the S-side. Spruce (mostly wspr) lichen forest with scattered bspr (also as »candelabrum» trees) and tamaracks. Snow cover here about 2 ½ feet deep. The area has been slightly cut. Bush layer of juniper and dwarf birch. The trees: *36 × 8,* age about 70 (rich cone formation) bspr 30 × 8 ½, age 55, wspr *27 × 5,* age 55—60. The bspr trees here have low ground branches, the wspr not.

Cryptogams: dominant *Cladina alpestris,* scattered *C. rangiferina* and *Cladonia ssp.* The lichen cover 3—4 inches thick. Epiphyte lichens on bspr on the plot: *Alectoria implexa, A. jubata, Cetraria ciliaris, C. pinastri, Evernia mesomorpha, Parmelia physodes, P. sulcata, Parmeliopsis aleurites, Ramalina Roesleri;* on wspr: *Alectoria implexa, A. jubata, Lobaria scrobiculata* (with *Rinodina turfacea*), *Parmelia physodes* and *P. sulcata.*

Reproduction: two 2-year old wspr seedlings, in the neighbourhood some tamarack seedlings, 2—3 feet high.

7. Fort George, burned and cut lichen forest near the HBC post. Secondary growth of bspr, wspr and scattered juniper and dwarf birch. The spruces about 5—7 feet high and 17—20 years old. One of the wspr: 5 × 1 ½, age 17 at the ground, with rich cone production (note the age). The annual growth in height: 1947 (16th July) 9 cm, 1946 16 cm, 1945 17 cm, 1944 15 cm, 1943 14 cm, 1942 12 cm, 1941 10 cm, 1940 12 cm, 1939 8 cm, thus fairly good growth on this poor site.

Cryptogams: dominant *Cladina rangiferina* and *C. alpestris,* incl. *Pleurozium Schreberi* and *Cladonia* ssp.

Reproduction: Apart from the young fairly wellgrown bushes of wspr and bspr also 3 wspr seedlings, 7 × 18—20 y, 7 × 15 y, 3 ½ × 8 y. Some of the bspr with vegetative propagation.

8. George River, in the centre of a large island, about 10 miles from the HBC post, about 30 feet above the river level in summer. Good bspr pulpwood and timber stand fairly fast growing. The biggest trees reach 48 × 12. Some dead tamaracks (in the neighbourhood plenty of tamarack in a *Ledum-Chamaedaphne* bog »forest»). The »group formation» of the spruce trees is evident. The sample plot represents a transition between bspr muskeg and bspr spruce lichen forest. The crowns are regular and branched to the ground. Some of the trees on the sample plot: 48 × 10, *45 × 8 ½,* age 75, *48 × 12,* age about 75, *39 × 8,* age 60, thus a good radial growth in evenaged stand, see Table XI.

Cryptogams: half of the area with lichens: *Cladina alpestris, C. mitis,* half with feather mosses[1]: *Pleurozium Schreberi, Hylocomium splendens.* Epiphyte lichens on bspr: *Alectoria nidulifera, A. jubata, Cetraria ciliaris, C. pinastri,*

[1] »Feather moss» means here *Hylocomium splendens, Pleurozium Schreberi* and *Ptilium crista-casirensis.*

Evernia mesomorpha, Parmelia physodes, P. ambigua, P. sulcata, P. hyperopta, Parmeliopsis aleurites, Ramalina dilacerata and *R. Roesleri.*

Reproduction: on the sample plot itself only a few old bspr seedlings. In the moister surroundings nearby fairly good reproduction of bspr seedlings, especially on decaying stumps with feathermoss cover: 13 × 16 y, 11 × 14—15 y, 10 × 13 y, 5 × 13 y, 6 × 13 y, 6 × 13 y, 4 ½ × 11—12 y, 7 × 11 y, 5 × 11 y, 4 ½ × 11 y, 4 ½ × 11 y, 6 × 9 y, 4 ½ × 9 y, 3 × 8 y, 5 × 6 y, 3 × 5 y, 2 ½ × 5 y. Some tamarack seedlings were of the following height and age: 6 × 14—15 y, 9 × 12 y, 6 × 12 y, 4 × 10 y, 4 × 8 y.

9. Loons Island, at the maritime tree-line an Empetrum-dominated maritime heath with scattered wspr in shelter by cliffs and a high thicket zone from the wind. Among the wspr scattered, bush-sized balsam poplar, juniper, dwarf birch and willow. The trees show no branches or very short branches on the windy NW side, the bark of the trees is very thin — resembling the bark of balsam fir — on the windward side in the barren zone owing to the snow cover; on this windward side the bast layer is unusually thick. The trees: *33 × 9,* age 65, *30 × 6 ½*, age about 50, *27 × 6 ½*, age 54. Thus, the radial growth is fairly good on these exposed trees.

Cryptogams: dominant *Hylocomium splendens* and *Pleurozium Schreberi,* scattered *Cladina rangiferina.* Epiphyte lichens on wspr: *Parmelia sulcata, Ramalina Roesleri.*

Reproduction-good. The following wspr seedlings noted: 6 × 24 y, 9 × 23 y, 5 × 22 y, 6 × 20 y, 7 × 17—19 y, 5 × 16 y, 8 ½ × 17 y, 5 × 13—14 y, 5 ½ × 11 y, 2 × 9 y, 2 ½ × 7—8 y, 8 × 11 y, 3 × 8 y, and 3 other wspr seedlings, 19, 20 and 21 years old respectively.

10. Loons Island, near the above mentioned locality. A wspr grove in the centre of the island. Wspr reaches here 36 feet in height and the balsam poplar 21 feet. Balsam poplar without shelter from the spruces are dry 6—9 feet above the ground. Scattered juniper, willow and *Rosa acicularis*-bushes. some of the trees: *36 × 19,* age 50—55, *33 × 8,* age about 55, *30 × 12,* age 65—70, *24 × 5,* age 45—50, thus fairly fast growing trees. The balsam poplars are probably 25—30 years (judging from one increment boring only).

Cryptogams: dominant *Hylocomium splendens,* incl. *Dicranum rugosum, Ptilium crista-castrensis, Drepanocladus uncinatus* and scattered *Pleurozium Schreberi.*

Reproduction: Fairly rich cone production on wspr. Regarding seedlings no notes.

11. Mainland coast of Long Island Sound, S of Little Cape Jones. Granite cliffs; the wspr forest occurs in scattered stands on small terraces between the cliffs, close to the sea, compare Fig. 3. The sample plot about 150 m from the shore and 30—45 feet above the sea level. Wspr reaches 30 × 10 here. In the ground vegetation maritime-arctic and common silvine elements intermingle. The trees are strongly wind-deformed and snow-damaged, about 40 % of the trees are dead. The snow cover is here 5—6 feet deep, and it lies late; the dwarf birch was still in flower July 27th. The pollination of the wspr was just finished. Some of the trees: *30 × 10,* age 140, *27 × 10, 24 × 8,* age 65, 8 × 2, age 50 at the ground.

Cryptogams: dominant *Hylocomium splendens*, incl. *Drepanocladus uncinatus*.

Reproduction: Good cone production, but no wspr seedlings on the sample plot. Nearby, however, several, mostly very depressed, bushy wspr seedlings: 7 × 44—45 y, 16 × 40—42 y, 10 × 26—27 y, 6 × 27 y, 11 × 17 y.

12. Black Whale Harbour, an old wspr stand between cliffs of Precambrian sedimentary limestone. The trees are strongly damaged by wind and snow, with deformed and eccentric crowns and habitus. The snow cover is here about 6 feet deep. Many trees have been broken by the snow. In the ground vegetation of the forest on the sample plot and in the other forest patches here maritime-calciphile and arctic elements intermingle with silvine elements. Some of the trees: *33 × 13* (rotten), age at least 180—190, 24 × 13, age at least 400 (rotten) at the ground, *27 × 12*, age 183.

Cryptogams: dominant *Hylocomium splendens* with scattered *Cladina alpestris*.

Reproduction: only a few, apparently very old wspr seedlings noted.

13 a. The maritime tree-line on an *island off the mouth of Beaver River*. A wspr forest patch on the eastern side of the island. In this small stand, about 1/20 acre, 9 bigger wspr trees reaching 24 × 10. The trees are strongly wind-deformed above the willow and dwarf birch thicket. In the ground vegetation maritime-arctic and silvine elements intermingle, as above. The trees are branched to the ground, no rooting of branches was, however, observed. The wood of these wspr was unusual hard; some trees show the same poor radial growth as does the bspr on muskeg habitats. Some of the trees: *24 × 10*, *24 × 9*, age 75—80, 24 × 16, age about 100, ½ feet above the ground, *21 × 5*, age at least 100. Wspr in flowering July 12th.

Cryptogams: dominant feather moss cover of *Hylocomium splendens, incl. Drepanocladus uncinatus*, *Brachythecium* sp., *Ptilidium ciliare*. Epiphyte lichens on wspr: *Ramalina Roesleri*, *Parmelia sulcata*.

Reproduction: Satisfactory cone production, but no seedlings on the sample plot. In the neighbourhood 3 seedlings observed, two wspr: 19 × 17 y, 9 × 13 y, and one bspr: 10 × 22 y.

(*13 b.* A small wind-exposed wspr grove with thick alder bush behind and between the trees on the same island as the above mentioned sample plot. Here 15 trees, about 21—24 feet high. The small stand seems to have been larger before, judging from stumps and roots in the surroundings. Two radial growth borings were made here (see No. 13 b in Table V) of the wspr: *24 × 4*, age at least 100 years, and *6 × 7*, age about 120 years. Many cones on the »trees». No notes regarding ground vegetation, seedlings (some in the barren heath around the stand, compare above) or cryptogams.

14. A granite island outside Fort George, about 6 miles W, near Goose Bay. Wspr forms small stands between the rocks on the island. The sample plot, about 1/20 acre, is a small wspr stand surrounded by alder bush (*Alnus crispa*). The trees on the plot: *27 × 16*, age about 100, 27 × 14, age about 100, *27 × 10*, age 30—35, 21 × 5, 15 × 4, age 25—26, 18 × 2. Thus partly a good radial growth which often is the case at the maritime tree-line; the trees are strongly wind-deformed.

Reproduction: good cone production. A few seedlings noted in the surroundings (not on the plot): 6 × 31—32 y, 15 × 24 y, 11 × 42 y, 11 × 21 y.

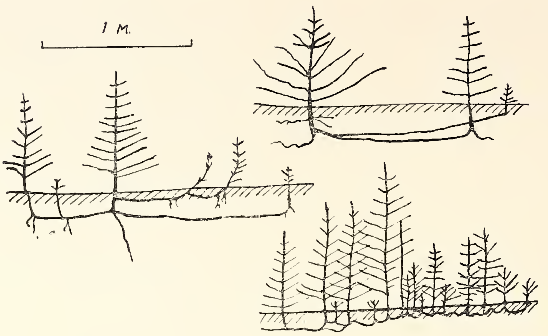


Fig. 11. Vegetative propagation of balsam fir near Rupert House, sample plot 16. The number of whorls of branches indicate approximately the age of the shoots.

15. Fort George. Secondary wspr stand in an alder thicket, 150 feet from the river shore about ½ mile W of the HBC post. Wspr reaches here about 39 × 10. Some of the trees (wide crowns, strongly branched) *39 × 10,* age about 65, *30 × 8,* age about 75, *30 × 10,* age about 70.

Reproduction: on the sample plot only one wspr seedling, about 6 years old. Also in the shadow of the alder bush in the neighbourhood some wspr seedlings seen.

16. Rupert House, a secondary balsam fir stand on the terrace above the river shore, ½—1 mile from the post, 30—36 feet above the river. Cut 5—10 years ago. In the balsam fir stand bspr thicket with strong vegetative propagation, also balsam fir thickets with vegetative propagation. See Fig. 11. Some of the balsam firs: *45 × 9,* age 60, at the ground about 70, *48 × 10,* age 85—90, *48 × 14,* age 128, thus timbersized trees.

Cryptogams: dominant feather moss cover.

Reproduction: 2—5 young balsam fir seedlings on every sq. metre. No bspr seedlings, but strong vegetative propagation of bspr and balsam fir.

17. Black Whale Harbour, about 1 ½ mile inland from the sea shore. Forest patches of young wspr, sheltered by cliffs. The sample plot, 1/20 acre, burned some 30 years ago, is now an even stand; samples of the trees: *24 × 5,* age 45, *27 × 8,* age about 50, *21 × 4,* age 33, 12 × 2 ½, age 35, 7 ½ × 2, age 50 and tamarack 12 × 3, age 40. Dense alder thicket (*Alnus crispa*), their stems are about 9 × 2—3, at least 25 years old.

Cryptogams: dominant *Pleurozium Schreberi, Hylocomium splendens* and *Ptilium crista-castrensis,* incl. *Dicranum* sp. and scattered *Cladina alpestris.*

Reproduction: good cone production on the wspr. On sample plot 7 wspr seedlings: 5 × 20 y, 5 × 20 y, 8 × 19 y, 4 × 18 y, 6 × 18 y, 6 × 15 y, 9 × 16 y. Near the shore the following wspr seedlings were noted: 12 × 43 y, 6 × 17 y, and two seedlings, 32 and 28 years old respectively. Also two tamarack seedlings, 8 × 14 y, 8 × 28 y.

18. George Island, moist wspr feather moss forest in the SW-part of the island, some metres above the river. Good pulpwood stand, on the average 36 × 6. Humus layer 7—8 inches. 12—15 feet high speckled alder (*Alnus rugosa var. americana*) thicket. The wspr are branchless up to 9—15 feet above the ground. (Balsam fir bush was noted in a similar locality some 100 feet from the sample plot.) Some of the trees: wspr *42 × 9,* age 80—85, *36 × 5,* age 83—85, *30 × 4,* age 84—85, 107 at the ground.

Cryptogams: dominant *Hylocomium splendens, Pleurozium Schreberi, Ptilium crista-castrensis.*

Reproduction: good cone production on wspr, but no seedlings on the sample plot.

19. George Island. A moist wspr feathermoss forest, slightly more wet than No. 18. About $^1/_4$—$^1/_2$ mile from the above mentioned sample plot. Thickets of speckled alder among the wspr. The highest wspr seen during the journey: *54* × *16*, age 160 years occurs here; other trees *48* × *9*, age 90—95, *42* × *16*, age at least 180 years, 36 × 6.

Cryptogams: dominant feather moss cover incl. *Rhytidiadelphus triquetrus.*

Reproduction: poor cone production and no seedlings on the sample plot.

20. Sucker Creek, about 1 mile inland from the low sandy shore near mouth of the river, a wspr feathermoss forest between the old dunes. No bspr seen in the area. Apparently sedimentary bedrock. Slightly snow-damaged crowns. Sample of trees: *36* × *10*, age 118, *27* × *7*, age 85—90, *24* × *6*, age 70. In the ground vegetation maritime elements intermingle with silvine plants.

Cryptogams: dominant feather moss cover: *Hylocomium splendens, Pleurozium Schreberi.* Epiphyte lichens on wspr: *Ramalina Roesleri, Alectoria lanestris, Evernia mesomorpha.*

Reproduction: except for some old low wspr bushes no reproduction was noted. The cone formation was, however, rich.

21. Sucker Creek. Near sample plot 20, but this wspr forest was more wet, a wspr muskeg forest, which seems to be common in the area. The trees grow in groups, as bspr in similar localities, indicating some kind of »candelabrum» formation. The stand about 1 mile from the shore; 15—20 % dead trees. Samples of trees: *30* × *11*, age 130, *27* × *6*, age 121, 27 × 5, age 122, and 18 × 3, age 35.

Cryptogams: mostly *Sphagnum Warnstorfianum, S. teres* and *S. parvifolium;* scattered feathermosses: *Pleurozium Schreberi, Hylocomium splendens,* incl. *Dicranum fuscescens var. flexicaule, Calliergon stramineum, Barbilophozia lycopodioides.* On the drier tussocks *Cladina rangiferina, C. mitis* and *C. alpestris.* Epiphyte lichens on wspr: *Alecto ia implexa, A. jubata, Evernia mesomorpha, Parmelia physodes, P. sulcata, Ramalina Roesleri.*

Reproduction: on the sample plot 8 wspr seedlings: 15 × 35 y, 4 × 35 y, 19 × 22 y, 9 × 19 y, 8 × 17 y, 6 × 12 y, 5 × 12 y, 4 × 15 y.

22. Rupert House. ½ mile SW of the HBC-station a bspr muskeg, cut over some years ago. The low trees reach 12 feet, with scattered low thickets of bspr, balsam fir and tamaracks, samples: bspr 6 feet, age 87 (1 feet above the ground), bspr 10 feet, age 48, balsam fir 9 feet, age 60 (1 feet above the ground).

Cryptogams: half of the area covered with *Sphagnum* ssp., the other, drier part with *Pleurozium Schreberi,* incl. *Dicranum rugosum* and *Cladina rangiferina.*

Reproduction: Fairly rich reproduction of balsam fir, about 1 seedling, 1—5 years old, on every sq. metre, the same amount of bspr seedlings. Strong vegetative propagation of bspr from the stumps.

23. George Island, an open bog in the central part of the low island. Scattered bspr and tamarack bushes, samples: tamarack 3½ feet high, 43 years old (half dead), bspr 2 feet high, 51 years old. In the ground vegetation typical bog and muskeg plants, see Table II.

Table 11. The ground vegetation on sample plots 1—24.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Empetrum hermaphroditum ..	×	×	—	—	×	—	1	—	3	2	2	3	3	—	×	1	—	—	—	1	2	×	×	—
Vaccinium vitis-idaea v. minus	×	1	—	2	×	×	—	×	1	2	—	1	1	×	—	×	1	—	—	×	—	×	×	—
Vaccinium angustifolium	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	1	—	—	—
Vaccinium canadense	—	—	×	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carex concolor	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hierochloe alpina	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Potentilla tridentata	—	×	×	—	—	—	1	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Epilobium angustifolium	—	×	—	—	—	—	×	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	×
Cornus canadensis	—	—	×	1	×	—	—	1	—	—	—	—	—	—	1	—	1	3	1	1	1	—	—	—
Ledum groenlandicum	—	—	×	1	×	—	—	2	—	—	—	—	—	—	—	1	—	—	—	×	—	3	×	—
Alnus crispa	—	—	—	×	—	—	—	—	—	—	—	—	—	3	3	—	—	—	—	—	—	—	—	—
Betula glandulosa	—	—	—	—	2	3	2	2	—	—	2	—	×	—	—	—	1	—	—	1	3	—	—	—
Vaccinium uliginosum	—	—	—	—	1	—	—	—	1	—	2	1	—	—	—	—	1	—	—	1	—	—	×	—
Lycopodium sitchense	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lycopodium complanatum	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Comandra livida	—	—	—	—	×	×	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	×	—	—
Linnaea borealis	—	—	—	—	—	×	—	—	—	×	—	—	—	1	×	—	—	1	2	—	—	—	—	—
Juniperus communis	—	—	—	—	—	×	×	—	×	×	×	—	—	—	—	—	—	—	—	×	—	—	—	—
Solidago multiradiata	—	×	—	—	—	×	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Deschampsia flexuosa	—	—	—	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Trisetum spicatum	—	—	—	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vaccinium cespitosum	—	—	—	—	—	—	2	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Lonicera villosa	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—
Trientalis borealis	—	—	—	—	—	—	—	—	×	×	—	—	×	1	1	—	—	—	×	—	—	—	—	—
Shepherdia canadensis	—	—	—	—	—	—	—	—	1	×	2	—	1	—	—	—	—	—	—	—	—	—	—	—
Rosa acicularis	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Salix glauca coll.	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table II (cont.)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Pyrola secunda	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arctostaphylos alpina	—	—	—	—	—	—	—	—	—	—	×	—	1	—	—	—	—	—	—	—	—	—	—	—
Lycopodium annotinum	—	—	—	—	—	—	—	—	—	—	×	—	×	—	—	—	—	1	—	—	—	—	—	—
Rubus acaulis	—	—	—	—	—	—	—	—	—	—	×	—	1	—	×	—	—	—	—	—	—	—	—	—
Oxytropis campestris coll.	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Carex scirpoidea	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Salix vestita	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	×	—	—	—	—
Polygonum viviparum	—	—	—	—	—	—	—	—	—	—	—	×	1	—	—	—	—	—	—	—	—	—	—	—
Solidago cfr macrophylla	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	×	—	×	—	—	—
Silene acaulis	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—
Luzula parviflora	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Viola cfr labradorica	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Moneses uniflora	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	×	×	—	—	—	—	—
Cerastium alpinum	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Pyrola grandiflora	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Lycopodium selago	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Rubus chamaemorus	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	×	—	—	—	×	×	—
Dryopteris spinulosa	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Ribes glandulosum	—	—	—	—	—	—	—	—	—	—	—	—	—	1	(2)	—	—	—	—	—	—	—	—	—
Rubus strigosus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	×
Rubus pubescens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	1	—	—	—	×	—	—	—
Equisetum arvense	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	1	3	—	—	—	—	×
Chiogenes hispidula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	×	—	—
Equisetum silvaticum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	×	—	—
Alnus rugosa v. americana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	2	—	—	—	—	—
Petasites palmatus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Coptis groenlandica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	—	—	—

Table II (cont.)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Heracleum lanatum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×
Petasites sagittatus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—
Tanacetum huronense	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—
Chamaedaphne calyculata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	×	—
Smilacina trifolia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	—
Oxycoccus cfr microcarpus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—
Carex cfr leptalea	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—
Drosera rotundifolia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—
Eriophorum russeolum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—
Eriophorum spissum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—
Kalmia polifolia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—
Carex limosa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—
Carex chordorrhiza	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—
Carex pauciflora	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—
Myrica gale	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—
Andromeda glaucophylla	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—
Scirpus cespitosus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—
Scirpus hudsonianus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—
Cornus stolonifera	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×
Urtica gracilis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×
Actaea rubra	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×
Mitella nuda	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×
Species (76)	2	6	5	5	9	8	9	5	6	9	10	8	17	8	11	6	9	7	7	14	7	11	(18)	8

Cryptogams: dominant *Sphagnum*-cover. Epiphyte lichens on bspr: *Cetraria ciliaris, Evernia mesomorpha, Parmelia sulcata, P. physodes, Alectoria nidulifera, Parmeliopsis aleurites, Usnea cfr plicata;* on tamarack: *Alectoria simplicior, Cetraria ciliaris* and especially *Evernia mesomorpha* (a lichen species which is very much liked by the caribou, according to information from indians at Fort George).

Reproduction: poor, scattered bspr seedlings: 10×16 y, $6\frac{1}{2} \times 15$ y, tamarack seedlings i.a.: 18×14 y, 12×11 y. Vegetative propagation by bspr and tamarack.

24. George River, the W-shore of a small island, 7—8 miles up the river. A balsam grove with rich bush and ground vegetation, incl. i.a. *Cornus stolonifera.* The balsam poplar reaches here 30×16. Most of the trees with dead crowns. One of the poplars, 30×14, was about 80 years old (DBH).

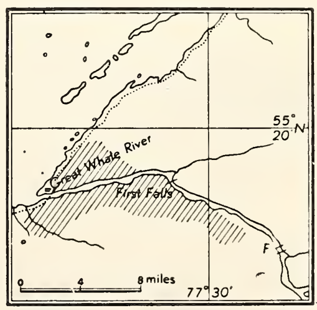
Part II.

5. General Notes on the Geography of the Great Whale River Area.

The bedrock in the Great Whale River area (below abbreviated to GWR area) is mainly granite and gneiss. Outside the mainland a zone of Precambrian sedimentary bedrock stretches along the coast. Erratic blocks of such origin are also distributed on the granite mountains near the coast, causing occasional favourable edaphic conditions for the vegetation.

Fig. 4, 12—51 give an idea of the general topography. The rolling low granite gneiss mountains along the river are mostly barren, the altitudinal difference of the relief being barely more than 300—500 feet. NE from the mouth of the Great Whale River a higher mountain massif stretches towards the north, attaining approximately 1,000 feet above sea level.

In the river valley there are sandy terraces broken by small creeks and brooks into deep ravines. The terraces are well marked in the lower part of the river. The elevated delta forms a large plateau at the mouth of the river. Open sand dunes occur frequently. There are no islands off the coast nearest to the mouth of the river. N of it the Manitounuk Islands (Precambrian sedimentary bedrock) shelter the coast. For further details compare Bell (1879), Low (1889, 1896, 1900), Marr (1948) and Kranck (1950). Map 2 shows the situation of the area approximately covered during the excursions, August 1st to August 26th 1947.



Map 2. The Great Whale River area. The shaded area gives an approximate picture of the forest area covered in Part II. The dotted line indicates the tree-line on the mainland coast.

Fig. 12. Great Whale River, Kayak Cove. Sheltered woods of white spruce below granite hills and sand dunes. Photo W. K. W. Baldwin.

Fig. 13. S of mouth of Great Whale River. »Inland lake with alder and willow thicket, closed white spruce forest with some tamaracks»; photo W. K. W. Baldwin.

The climate is of an arctic-maritime type; the central part of Hudson Bay lies open off the coast. The short and cold summer has its warmest period in August. Table III shows the average monthly temperature and precipitation at GWR according to Connor (1938, period 1925—31) and Marr (1948, 18 years observations, period not mentioned). Marr's figures are in Fahrenheit and inches, and are here converted into centigrade and mm.

Table III. Mean temperature and precipitation at GWR.

	I	II	III	IV	V	VI	
Connor:							
temperature ..	—24.4	—22.9	—15.3	—8.9	0.7	6.3	C°
precipitation ..	—	—	—	—	—	6	mm
Marr:							
temperature ..	—23.8	—22.8	—17.2	—7.2	0	6.1	C°
precipitation ..	40.6	15.2	20.3	17.8	38.1	58.4	mm
	VII	**VIII**	**IX**	**X**	**XI**	**XII**	
Connor:							
temperature ..	8.9	10.1	7.4	1.8	—6.0	—14.7	C°
precipitation ..	80	86	88	—	—	—	mm
Marr:							
temperature ..	9.4	10.5	7.2	1.6	—6.6	—16.6	C°
precipitation ..	71.1	96.5	88.9	91.4	88.9	58.4	mm

Diagram 1 gives a comparison between GWR and 3 other stations on the Hudson Bay coast; see p. 10.

*

The GWR area lies on the transition zone between the taiga and the forest-tundra, see Map 1 and 2, and the maps in H 1949. Map 2 shows the tree-line which extends almost to the shore line in this part of the Hudson Bay coast. On the E side of the islands W of Manitounuk Sound there is spruce forest in the sheltered valleys. The general character of the wooded country along the river is apparent from Fig. 14—15. Seen from the air the forest occupies only a third to one half of the area along the coast, but becomes, of course, gradually more dominant inland.

The transitional character of the area, a »forest-tundra ecotone» (sensu Marr 1948), is clearly reflected in the forest and in the ground vegetation in general. The coastal influence on the shore vegetation extends about 2 miles

Fig. 14. Typical white spruce lichen forest on the elevated delta near mouth of Great Whale River. Photo W. K. W. Baldwin. Compare Figs. 11, 16 and 17 in MARR 1948.

inland, i.e. more or less to the tide water limit up the river. The »fog belt» on the coast seems to influence the vegetation for 7—8 miles inland. The mountain slope vegetation looks more »wet» along the coast zone than the mountain slope vegetation farther inland. The treeless sand plateau on both sides of the river mouth shows, in part, an arctic vegetation.

The mountains in the GWR area are in general too low to develop a typical vertical tree-line. The alder and tamarack belt is not as clearly developed here as on the Atlantic coast of the Labrador Peninsula. The higher mountains show a »triviale» alpine flora of *Loiseleuria procumbens, Juncus trifidus* etc. The dry mountain heaths are dominated by *Empetrum hermaphroditum* and *Vaccinium uliginosum* var. *alpinum,* the commonest »blueberry» species in the area.

The shores of the river are partly clayey (underneath the sandy terraces) and are mostly, as also the shores of the lakes (see Fig. 13), covered with a thick alder or willow thicket, including glandular dwarf birch and Labrador tea. The importance of the alder thickets as a pioneer formation for the spruce forest should be noted.

The author saw but few bogs. From the air some large bogs were seen south and north of GWR, seemingly of the same »aapa»-type as the bogs in the eastern part of the Labrador Peninsula described by WENNER 1948. A larger so-called »palsa» bog was observed about 10 miles inland. The 15—18 feet high »palsas» were partly deformed and eroded. *Eriophorum spissum, E. russeolum* and *E. angustifolium* dominated the wet areas between the »palsas». Their structure seemed to resemble that of the palsa bogs on the

Fig. 15. Hill top view behind First Falls, Great Whale River. Photo W. K. W. Baldwin.

east coast of the Labrador Peninsula, see the author's paper 1939. It seems that this type of bog is typical for the transition zone between taiga and tundra, i.e. the forest-tundra. It also, probably, forms the southern limit of the real permafrost region. Compare also PORSILD's notes on much larger palsa bogs with up to 300 feet high »pingos» from the (unglaciated) Mackenzie area (1939).

*

The flora comprises about 325 species of vascular plants. This statement is based on BALDWIN's list of plants on the east coast of Hudson Bay (1949) and on my own observations. The GWR area is thus poor in species, and it is,

in this respect, probably typical of the large interior E of the small area covered by us.

The influence of man is still very small in this area. Except for some minor cuttings around the HBC post the GWR area is covered by virgin forest and is therefore suitable for the type of investigation desciibed below.

6. The Tree and Bush Species in the GWR Area.

In the lower GWR area the following tree species occur: white spruce, *Picea glauca* (Moench) Voss, black spruce, *Picea mariana* (Mill.) B.S.P., tamarack, *Larix laricina* (DuRoi) Koch, and balsam poplar, *Populus balsamifera* L. According to Low (1896) white birch and balsam fir occur in the hinterland farther along the south branch of the river. According to information received at the HBC-post jack pine grows about 80 miles up the river along the south branch of the river. However, only the four tree species mentioned above were seen during the excursions in 1947.

White spruce.

The sandy and partly clayey alluvial deposits along the river and the elevated delta around the mouth of the river provide favourable edaphic conditions for white spruce. This species dominates the forest nearest to the shore and on the terraces along the lower parts of the river. Inland from the so-called First Falls, see Map 2, only occasional white spruces were seen (for instance, a few trees on a small old dune area around a lake SE from First Falls, about 300 feet above the river) away from the river terraces.

On the elevated delta with its old rolling dunes, white spruce forms an open »park forest» with fairly low and bushy trees, often young and fast growing, on a white lichen heath with scattered vascular plants. On such areas white spruce also forms low carpets similar to the carpets more often formed by the black spruce in exposed areas. The »candelabrum» tree form, see p. 42, usually occurs among black spruce, but on this elevated delta white spruce candelabrum trees can be seen, sometimes composed of 30 stems.

The maritime tree-line runs near the shore line and is, without exception, formed by white spruce, rich in cones in 1947. On such exposed localities cones of teralogical interest could be found on the white spruces, i.e. cones with needles or male inflorescences in the top of the cone, see Fig. 5. In such exposed habitats even white spruce shows vegetative propagation, i.e. rooting of old long branches.

White spruce generally grows faster than black spruce. But in northern

Fig. 16. Section at the ground of a white spruce (30 feet high, 150 years old) from the terraces inland from Great Whale River, near sample plot 29. Note the slow growth in thickness in the last decades; the section shows a feature generally characteristic of black spruce.

and exposed areas white spruce sometimes grows extremely slowly, compare the section in Fig. 16. For more details regarding the growth in height and in thickness of white spruce, see Part III. White spruce does not reach strikingly larger dimensions than black spruce in this area. The biggest white spruce tree seen by the author in the GWR area was about 45 feet high and 16 inches in DBH; Gardner and Wilmot (1943) report spruces measuring 24 inches from GWR.

The commonest white spruce forest type in this area is the white spruce-lichen forest or the white spruce-dwarf shrub-lichen forest, dominant types on the sandy terraces, compare also Fig. 16 and 17 in Marr 1948. Farther south on the coast, where the influence of the Precambrian sedimentary bedrock is more evident (Sucker Creek, for instance) richer white spruce forest types can be seen; see p. 31 above. — Some facts regarding the reproduction of white spruce are collected on p. 60.

White spruce was, at least in August 1947, more infected by *Chrysomyxa* cfr *Ledii* (det. Dr. V. Kujala) than black spruce in the area. Almost all white

spruce trees, including seedlings, showed at least some twigs infected by this fungus in August 1947.

Black spruce.

Black spruce is less common than white spruce in the area nearest to the mouth of the river and does not reach the maritime tree-line. Occasionally only black spruce is found on the elevated delta. On the slopes of the low granite-gneiss mountains black spruce gradually becomes more common and already on terraces 2—3 miles inland along the river black spruce is as common as white spruce. Farther inland black spruce dominates the pulpwoodsized forest in the river valley. Good and evenaged black spruce stands are among the sample plots described below.

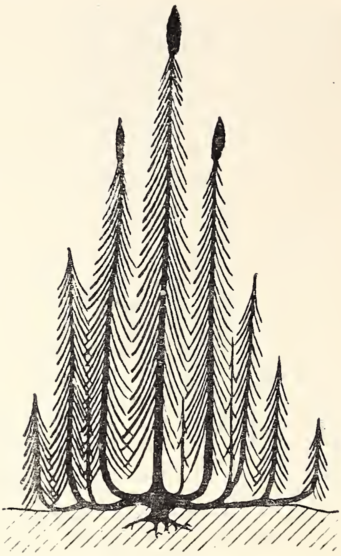


Fig. 17. A »candelabrum» black spruce, a tree form which is characteristic in the black spruce lichen forests in Labrador, see H 1949, p. 37, usually 20—25 feet high only.

The vegetative propagation capacity of black spruce is a well-known feature, as is also its capacity to form adventitious roots, compare H 1950. Its slow growth and eccentric radial growth on muskeg areas are also common characteristics for black spruce. On lichen heaths the black spruce fairly frequently forms »candelabrum» trees, whereas white spruce more rarely attains this shape; see, however, p. 40. A more closely studied candelabrum black spruce, see Fig. 17—20, near sample plot 29, had 37 stems, of which 13 bigger stems, 6—23 feet high. Of these 4 stems were over 18 feet high. The age of the tree was about 90 years at the ground. The root reached only 1 feet deep into the sandy soil (on a terrace S of the river, about 2 $^1/_2$ miles inland from the HBC post). The »nutrition roots» (a tentative expression used here to mark the unusual character of the adventitious roots by this tree form) are formed by many small roots *above* the big »roots» or branches, which turn upward forming the stems of the candelabrum tree; see Fig. 19.

This form of black spruce seems to be common all over the Labrador Peninsula on lichen heaths. The author has, for instance, seen this tree form on lichen heaths near Rigolet on the Labrador coast, in Oskelaneo in SW part of the Peninsula, in the Knob Lake area in the central part of the Penin-

Fig. 18. The »candelabrum» black spruce described on p. 42. The lowest branches are cut to show the many stems growing from the same main root; compare Fig. 19.

sula etc. The development into a candelabrum tree is already marked in young seedlings.

The black spruce forms thickets and carpets more readily than white spruce. In some places near the maritime tree-line at GWR white spruce attains tree size, where black spruce forms only creeping carpets.

The biggest black spruces seen by the author in the area were only 39—42 feet high and 14—16 inches (DBH). — Some facts regarding the reproduction of black spruce appear on p. 60.

Tamarack.

This species occurs generally only intermingled among the spruces, usually in moist and wet habitats, on mountain slopes etc., compare, however, sample plot 28 below. Tamarack does not extend as far to the maritime tree-line as does the spruce. Also on the mountains, tamarack seems to be less hardy than the spruce species. The fairly distinct tamarack belt, which can be seen on the coast mountains on the Atlantic coast of the Labrador Peninsula, does not exist in the GWR area.

Fig. 19. Scheme of the ground part of a candelabrum black spruce; simplified.

Usually the tamarack forms stands of 10—20 trees only, on sloping small fens or bogs. A specific habitat for tamarack in the area are the small fens with *Scirpus cespitosus* and *Potentilla fruticosa* as dominant vascular plants, see sample plot 14 below. Many of the tamarack trees, at least near the coast, are half dead and have heart or stem rot, see Fig. 27. On this section of a tamarack tree (on sample plot 39) one also clearly observes the very uneven growth in thickness of this species. This irregular growth is caused by insect injuries which more easily affects this species than it does spruce.

The biggest tamarack tree seen on our excursions was only 42 feet in height and 10 inches in DBH. Tamarack forms easily adventitious roots. Its reproduction does not seem to be as good in the GWR-area as, for instance, in the Knob Lake area of the interior.

Fig. 20. Ground section of the candelabrum black spruce described on p. 42.

Balsam poplar.

Only one locality for balsam poplar was seen in the area covered by us. It was a small grove on a mountain slope 15—16 miles inland from the HBC post. This balsam poplar stand, see sample plot 44 below, is one of the northernmost localities for this species in the western part of the Peninsula. From Richmond Gulf MARR reports (in letter) two balsam poplar stands, one »on a flood plain of a river on the S-shore of Richmond Gulf», the other in a »narrow ravine E of the mouth of Wiachawan River», seen by him in 1939. On the Wiachawan locality the balsam poplar reached 30 feet in height and 8 inches in diameter.

The Bush Species in the GWR-forests.

The commonest bush species in the GWR-forests is the glandular dwarf birch, *Betula glandulosa* Michx. which occurs in almost every forest type, see Table II—IV. *Betula pumila* L. was not observed. A bushy species of »white birch» in the GWR area, *Betula minor* (Tuckerm.) Fern. (det. A. E. PORSILD) was found near the river mouth on a low mountain slope in 1947 (about 10 feet in height and 2 inches in diameter). According to communication by MARR (in letter) E. ABBE found in 1939 »a few dwarfed white birch» (= *Betula minor* or *B. papyrifera?*) in the Richmond Gulf area.

Alder, *Alnus crispa* (Ait.) Pursh., is very common on the shores of the rivers, creeks and lakes. This species had, at least in 1947, a very rich fructification, whereas the other alder species in the area, *Alnus rugosa* var. *americana* (Regel) Fern., had poor fructification; it was found in a few localities along the river. On the mountain slopes alder thickets were not as common as on the mountains on the Atlantic coast of the Peninsula. The flora in the sheltered »nitrogenous» soil of the alder thickets consisted of high herbs, usually not seen in other habitats in the GWR area, such as *Streptopus amplexifolius, Athyrium angustum, Rubus strigosus, Agropyron trachycaulum* etc. *A. crispa* var. *mollis* Fern. (earlier *A. mollis* Fern.), a hairy form of the common *A. crispa*, was collected some 15 miles from the HBC post on the river bank.

The commonest willow species in the GWR area are probably *Salix planifolia* Pursh., *S. pedicellaris* Pursh. and *S. glauca* coll., compare Part I. Regarding the willow flora in the Hudson Bay region, compare RAUP 1943.

Juniper, *Juniperus communis* coll., was occasionally seen on wooded mountain slopes, see also Table IV. Mountain ash, *Sorbus decora* (Sarg.) Hyland. var. *groenlandica* (Schneid.) Jones, was seen only in a few localities. Mountain ash was in rich flower in the beginning of August. These species play an unimportant role in the forest vegetation. The same applies to *Ame-*

anchier Bartramiana (Tausch.) Roemer and *Viburnum edule* (Michx.) Raf. which occur scattered only. Of the *Ribes*-species, *Ribes glandulosum* Grauer is probably the commonest. Wild cherry was not seen in the area, see p. 19.

7. Sample Plots, 25—45.

In Table IV the ground vegetation, including the bush species, on 20 sample plots is mentioned. Regarding the size of the sample plots and the abbreviations used, compare p. 25 above. Of the 20 sample plots described below four (25, 29, 39 and 43) are called »permanent» sample plots. On these every seedling has been marked in the field and described in detail (these descriptions are not included here) for reference, should the author in the future get the opportunity of again visiting the same area.

25. Permanent sample plot, about 42×75 feet, on the elevated delta S of the HBC post, about 1 mile from the river shore and about $^{1}/_{4}$ mile from an open dune terrain, see Fig. 12. Dominant wspr, appearing partly as candelabrum trees. The surface is slightly rolling, with low depressions, 2—3 feet only, where trees and seedlings occur, see Fig. 21. On the sample plot a large group (partly a candelabrum tree) with 20 stems of the sizes: 4×1 (regarding the meaning of the expression 4×1, see p. 25) — 24×5 with several hundreds of well developed new cones in 1947. The biggest stems: 24×5, age 34, 23×4, age 28, 21×6, age 54 and 21×4 age 31, thus fairly fast growing trunks, considering the extreme conditions. On sample plot 1 there are 4 minor solitary trees: 23×8, age 53 (an annual radial growth of 2—3 mm), with about 1,000 cones, 15×5, with about 1,000 cones, $12 \times 2\ ½$, age 27, with 15 cones, 15×5, no cones.

On the elevated delta wspr seem to penetrate into new territory. No old stumps could, for instance, be seen near the shore. The trees look luxuriant and show a remarkably fast growth after they have passed the »depressed stage», compare the age of the seedlings mentioned below. Many trees in this area have double stems.

Cryptogams: dominant *Cladina* cover, mostly *C. rangiferina*, incl. *C. alpestris*, *C. mitis*, *Stereocaulon* sp., *Cetraria nivalis* and *Alectoria* sp. Epiphyte lichens: *Evernia mesomorpha*, *Parmelia physodes*, *P. sulcata*, *Ramalina Roesleri*. Under the trees (as is usual in spruce lichen forests): *Pleurozium Schreberi* together with *Empetrum hermaphroditum* and *Vaccinium vitis-idaea* incl. one *Ribes glandulosum* seedling.

Reproduction: On the permanent sample plot, about 1/15 acre, 20 wspr seedlings were counted. They were very similar in age and height to the 16 wspr seedlings mentioned below. Of the 20 seedlings 11 were slightly damaged by frost and partly deformed. No seedlings grow on the »top» of the old dunes, which were covered with scattered *Epilobium angustifolium* and *Campanula rotundifolia* and lichens. Instead, the seedlings grow in the small plain depressions (wind shelter, but also frost). 16 wspr seedlings were collected immediately outside the permanent sample plot, their height and age: 8×15 y, 7×16 y,

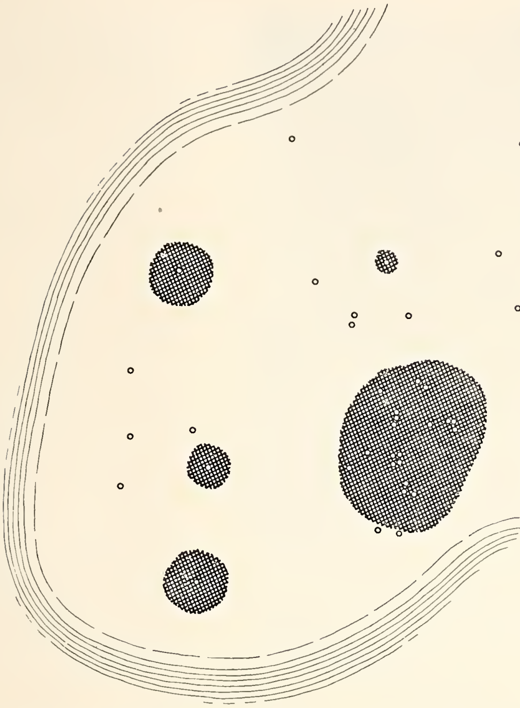


Fig. 21. Sketch of sample plot 25. The checkered areas are white spruce, the open dots outside the checkered areas white spruce seedlings. The lines mark the slight depression in which the spruces grow on this elevated delta near Great Whale River. The sample plot is about 42 × 75 feet.

6 × 15 y, 6 × 15 y, 6 × 14 y, 6 × 13 y, 6 × 13 y, 6 × 11 y, 5 × 13 y, 5 × 13 y, 5 × 12 y, 4 × 10 y, 4 × 10 y, 2 × 10 y, 2 × 7 y, 1 ½ × 8 y.

26. N of the river, about 1 mile from the mouth, on the upper terrace, about 300 feet above sea level (?), near the granite hill. White spruce lichen forest of a poor type common in this area; the trees are mostly arranged in groups. Snow cover 1—3 feet deep, judging from the branchless parts of the spruce stems and the glandular dwarf birch shrub in the vicinity. Samples of trees: 30 × 6 ½, age 75; 24 × 3 ½, age 52, at the ground 70, 23 × 3 ½, age 54, at the ground 72, 21 × 3, age 55, at the ground 75. The crowns of the trees are narrow.

Cryptogams: dominant *Cladina*-cover (*C. mitis* and *C. alpestris*), including *Alectoria ochroleuca, A. nigricans, Stereocaulon* sp., *Cladonia* ssp., *Parmelia physodes, Cetraria caperata.* Under the trees: *Dicranum rugosum* (and *Vaccinium vitis idaea* and *Empetrum hermaphroditum*).

Reproduction: On the sample plot only 2 wspr seedlings. On a similar area around the sample plot 14 wspr seedlings, their height and age: 32 × 45 y, 28 × 45 y, 12 × 29 y, 10 × 38 y, 10 × 30 y, 7 × 40 y, 6 × 31 y, 6 × 30 y, 5 × 38 y

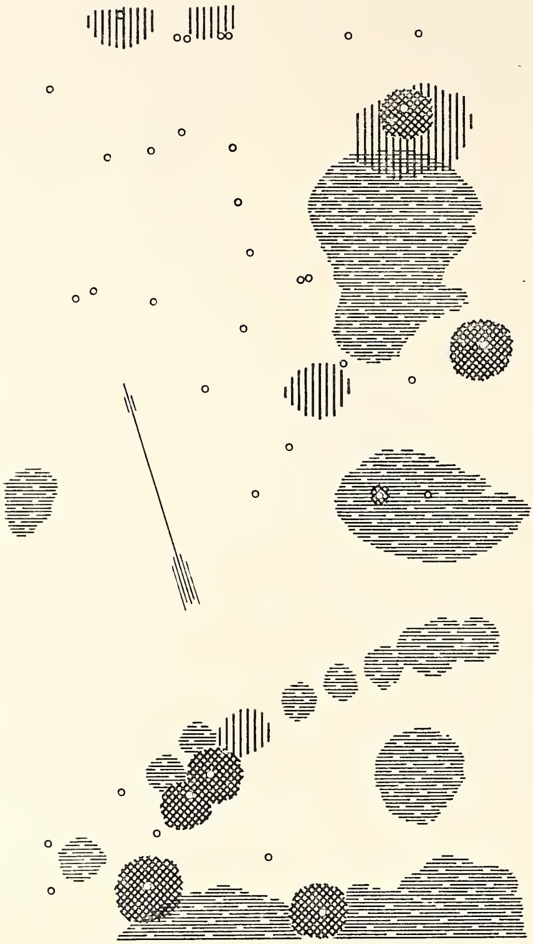


Fig. 22. Sketch map of sample plot 29, about 24×72 feet. The checkered areas are white spruce trees, the horizontal shading indicates Betula glandulosa bushes, the vertical shading Ledum groenlandicum bushes. The open dots are white spruce seedlings on the plot covered with lichen. Slight slope northwards.

5×30 y, 5×17 y, 4×12 y, 3×16 y, 3×12 y. Thus, the growth in height of the seedlings is extremely slow on this sample plot.

27. A sandy plain between two low hills about 15 miles inland from the HBC post, about 300 feet above the river. Dominant black spruce which here reaches on the average 21×4. Several old trees and stumps were seen in this black spruce lichen forest as were also scattered low bspr bushes. The trees look old, though, the increment borer proved that these trees were unexpectedly young; some samples: 24×6, age 30, 21×4, age 25, at the ground 43, $18 \times 3\ ½$, age 23.

Cryptogams: dominant *Cladina alpestris* cover, incl. *C. mitis* and *Stereocaulon* sp. On the trees *Alectoria jubata.*

Reproduction: No seedlings on the sample plot itself, nearby a bspr seedling 7×21 y.

28. Black spruce lichen forest near the sandy plain S of the First Falls, about 8 miles inland from the HBC post, about 120 feet above the river. Scattered tamaracks grow among the dominant black spruce. Samples of trees: bspr 27×5, age 80, 24×5, age 71, few cones on bspr; tamaracks 27×6, age about 77, 27×5, age about 67, no new cones on the tamaracks.

Cryptogams: dominant *Cladina alpestris* cover, incl. *C. mitis* and *C. rangiferina.*

Reproduction: not noted.

29. Permanent sample plot of white spruce-dwarf shrub-lichen forest type

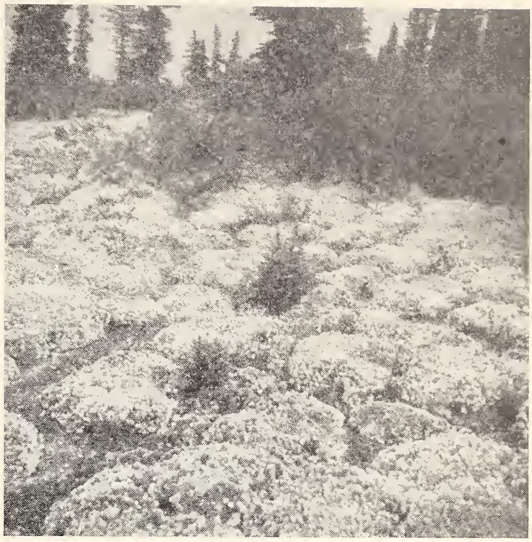


Fig. 23. View from the SE corner of sample plot 29. Note the »flakes» of the Cladina cover and the depressed growth of old white spruce seedlings. In the background Betula glandulosa.

on a terrace about 150 feet above the river, about 2 ½ mile inland from the HBC post, see Fig. 22 and 23. Snow cover about 2—5 feet above the ground; the branchless parts of the stems are developed on the windy NW side. All of the trees show branches on the ground and above it a branchless part, the height of which varies according to the varying height of the snow cover of the plot. The trees show rich cone formation. The trees on the sample plot: 33×8, age 103—105; 27×5, age 83; 26×4, age 105; 30×8, age about 100; 24×4, age 72; $23 \times 4\frac{1}{2}$, age 65. The mean value of their growth in thickness appears in Tab. X.

Two wspr trees near the permanent sample plot were cut. One of them was 30 feet high, $6\,^1/_3$ inches in diameter at the ground and $5\,^1/_3$ inches DBH, age 150 years at the ground. The tree had only 52 new cones 1947 and more than 1,000 male inflorescences, situated between 3 feet from the top and 6 feet from the ground; cones 2—3.2 cm long, in the top part of the tree, i.e. the normal arrangement of inflorescence in spruce. Growth in height during the period 1935—47 appears from Table VI. The other tree was 25 ½ feet in height, 6 inches in diameter at the ground, 3 ½ inches DBH, age 125 years at the ground; 96 new cones, 1—4 cm long. Note the difference in length of the cones between these two trees growing beside each other. Thousands of male inflorescences. Growth in height is nearly the same.

The black spruce »candelabrum tree», described on p. 7, belonged to this type of forest (some 400 feet from the sample plot, on the same terrace).

Cryptogams: Dominant *Cladina alpestris* cover, incl. *C. rangiferina* and *C. mitis*, scattered *Stereocaulon* sp., *Cetraria nivalis*, *Alectoria ochroleuca*, *Cladonia* sp., *Polytrichum juniperum* (cfr).

Reproduction: On the sample plot, about 24×72 feet, 48 wspr seedlings, all marked with sticks for future examination. Of these 48 seedlings, 13 had double stems or otherwise showed indications of a »candelabrum tree» form in an early stage. 16 seedlings were more or less deformed. Outside the permanent sample plot 16 wspr and bspr seedlings were collected on a similar

Fig. 24. One of the white spruce seedlings, in 3 inches high Cladina cover, sheltered by Ledum groenlandicum bush; sample plot 29. Probably 15 years old.

lichen heath with scattered dwarf shrubs: wspr 12×44 y, 10×45 y, 7×30 y, 7×30 y, 15×25 y, 7×51 y, 7×18 y, 6×21 y, 5×30y, 5×25 y, 5×18 y, 3×16y, 2×9 y, bspr 10×25 y, 4×18 y, 3×14 y. These age determinations show how uncertain the relation between height and age is on localities with »depressed growth»;see Diagram 4 and Fig. 24.

The seeds of spruce germinate fairly easily in the narrow furrows between the lichen flakes, see Fig. 25. In such furrows seeds of vascular plants also germinate fairly easily and slowly penetrate into the lichen heath. Spruce seedlings which develop in the shelter of *Ledum groenlandicum* or *Betula glandulosa* are usually less deformed than the seedlings in the open lichen cover.

30. About 15 miles inland from the HBC post, a gentle S-slope near a low hill S of the river. Good pulpwood sized black spruce forest, no candelabrum trees. The forest is fairly dense, the trees have narrow crowns, with small or no branches at all in the lower part of the crown. About 10 % dead trees. The sample plot represents probably an old lichen forest developing into a feather moss climax stand. The growth in thickness is extremely slow, note the relation of diameter to age: 39×8, age 120; 39×6, age 190; 27×5, age 190; 27×4, age 177. Very few cones noticed.

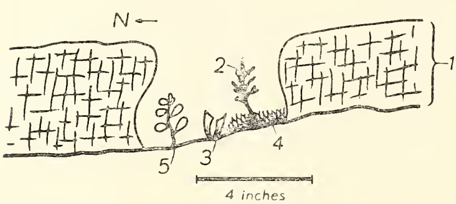


Fig. 25. Sketch drawing showing a white spruce seedling (2) in a furrow between Cladina alpestris flakes (1), Cladonia sp. (3), Pleurozium Schreberi (4) and small Vaccinium vitis-idaea (5). The seedling probably 7—9 years old.

Cryptogams: half of the sample plot covered with lichens: *Cladina mitis, C. rangiferina, C. alpestris, Nephroma* sp., the other half with feather mosses: *Pleurozium Schreberi, Hylocomium splendens,* incl. *Dicranum fuscescens* and *D. rugosum.*

Reproduction: Neither seedlings nor vegetative shoots.

31. 18—19 miles inland from the HBC post a transition area between a black spruce lichen forest and a black spruce feather moss forest.

Good pulpwood sized black spruce stand between a low hill and a brook. No candelabrum trees. Scattered bspr bushes between the trees. Slow growth in thickness, few cones. Samples of trees: 42 × 8 ½, age 171; 42 × 8, age 160; 39 × 9, age 165; 8 × 2, age 87.

Cryptogams: About half of the sample plot covered with lichen: *Cladina mitis, C. alpestris, Nephroma* sp., the other half with feather mosses: *Pleurozium Schreberi* and *Hylocomium splendens.*

Reproduction: No seedlings, some 4—8 inch high vegetative shoots.

32. 13 miles inland from the HBC post, on a fairly wet and steep NE-slope, a typical black spruce feather moss forest. The trees here, however, are strongly branched; the branches are turned downwards. Old, decaying stems (up to 20 inches in diameter) on the sample plot, which is probably typical for the moist mossy slopes of the river valley. Samples of trees: 36 × 10, age 125; 36 × 8, age 78; 27 × 5, age 84. Very few cones. The trees are usually fairly eccentric. On about 1/40 acre 2—3 decaying trees and 2—3 standing dead trees.

Cryptogams: dominant feather moss cover: *Hylocomium splendens, Pleurozium Schreberi, Dicranum rugosum,* incl. scattered *Nephroma* sp., *Cladina rangiferina, C. alpestris.*

Reproduction: no seedlings; a few vegetative shoots.

33. About 17—18 miles inland from the HBC post, a plain area between low hills S of the river, a black spruce feather moss forest, partly »candelabrum» trees. Few new cones on the trees. Nearby some tamaracks. As on the above described sample plot *Vaccinium vitis-idaea* grows only under the trees. Sample of trees: 36 × 7, age 87; 27 × 6, age 88; 27 × 6 ½, age 74.

Cryptogams: dominant feather moss cover with *Hylocomium splendens, Pleurozium Schreberi,* incl. scattered *Dicranum* sp. and scattered *Nephroma* sp., *Cladina alpestris, C. mitis, C. rangiferina.* Epiphyte lichens: *Alectoria jubata, A. simplicior, Cetraria ciliaris, Evernia mesomorpha* and *Parmelia sulcata.*

Reproduction: No seedlings.

34. S-slope in a narrow valley along a brook, about 1 ½ miles S of the mouth of the river. A fairly well developed white spruce stand, representing a *Vaccinium* feather moss forest of rather unusual character. Some trees reach 45 × 10—12, usually strongly branched. The stand is fairly evenaged: 36 × 8, age 82, 33 × 6 ½, age 77, 33 × 6, age 80, 27 × 4, age 71. Near the sample plot a wspr 42 × 14, age at least 140, heart or stem rot; the biggest trunks (some cuttings have been made here for the settlements huts) measured 16 inches in diameter. The sample plot is only $^{1}/_{3}$ mile from sample plot 25, and a comparison shows the importance of shelter from wind in this exposed coast zone. The crowns usually narrow. Slope 40—45°.

Cryptogams: dominant feather moss cover under *Betula glandulosa* and *Vaccinium vitis-idaea: Pleurozium Schreberi, Hylocomium splendens, Ptilium crista-castrensis, Dicranum* sp. and scattered *Nephroma* sp. and *Cladina* sp.

Reproduction: no notes.

35. Black spruce blueberry forest near the First Falls, about 9 miles inland from the HBC post, about 100 feet above the river, near a small brook. The biggest trees reach about 40 × 16.25 % dead trees. Uneven stand with old trees and bushy young trees together. Samples of trees: 39 × 16 (half dead), age 139,

½ foot above the ground, 24 × 6, age 80, 21 × 6 ½, age 90, 12 × 2 ½, age 37 at the ground, with cones. Nearby some tamaracks.

Cryptogams: dominant feather moss cover under *Vaccinium canadense, Pleurozium Schreberi, Hylocomium splendens, Ptilium crista-castrensis* incl. scattered *Dicranum majus* and *Sphagnum capillaceum.*

Reproduction: no seedlings; few vegetative shoots.

36. Mountain slope forest on a small granite hill about 1 mile inland from the HBC post, a transition between the sample plots 26 and 37. A mixed, poorly developed stand with abundant white spruce and scattered black spruce and tamarack, a kind of forest which is frequently seen near the river. Samples of trees: wspr 10 × 3, age 52 at the ground, about 30 new cones, bspr 6 × 2, age 46 at the ground, no cones, tamarack 24 × 7, age 80, some cones on the lower branches. Generally in this area many cones on white spruce, almost none on black spruce. Nearby tamarack reaches 27 × 7, wspr 24 × 5 and bspr 24 × 5.

Cryptogams: dominant feather moss cover under *Ledum groenlandicum* etc. see table IV, *Pleurozium Schreberi, Hylocomium splendens, Ptilium crista-castrensis* and *Dicranum* sp.

Reproduction: No seedlings, few vegetative shoots (bspr).

37. Similar forest on SW-slope of a low granite hill about 1 mile from the HBC post, about 150 feet above the river. Abundant black spruce, a few white spruces and tamarack just outside the plot. Scattered *Alnus crispa*-bush; stony soil. Some of the bspr have a slightly developed candelabrum form. Samples of trees: wspr 27 × 8 ½, age 155, no cones, wspr 18 × 6, age about 100, few cones, bspr 23 × 4 ½, age 47, no cones, bspr 21 × 4, age 75, no cones. Black spruce seems to be penetrating into an earlier white spruce forest.

Cryptogams: dominant feather moss cover under *Ledum groenlandicum, Betula glandulosa, Vaccinium vitis-idaea* etc.

Reproduction: no seedlings.

38. Tamarack swamp on a gentle slope of a low hill 8—9 miles inland from the HBC post, about 180 feet above the river. This sample plot is typical for the small tamarack fen forests on the moist mountain slopes in the area. Scattered black spruces. Few cones (mostly on old low branches); on some more or less deformed tamaracks outside the sample plot rich cone formation. Sample of trees (tamaracks): 27 × 6, age 70, 27 × 4, age 55—60, 21 × 3, age 55, all fairly well grown tamaracks, which is not usual in this district.

Cryptogams: Sphagnum and »brown moss» cover.

Reproduction: no notes.

39. Permanent sample plot, about 30 feet above the river, on a gentle moist slope $^1/_5$ mile from the N-shore of the river, 1 mile from the HBC post, in an area where the inhabitants frequently cut wood and branches for their tents. The sample plot (Fig. 26) thus shows the effect of a slight thinning; note the increased amount of vegetative shoots. Fairly wellgrown white spruce, half dead tamarack and black spruce brush struggle on the sample plot, separated by willow, glandular dwarf birch and Labrador tea thickets. Fig. 27, a section of a tamarack, some inches from the ground, was taken immediately outside the sample plot. The section shows heart or stem rot, typical for tamarack in this area. Note also the characteristic irregular growth of the tree.

The white spruces on the plot are the following: 30 × 7 ½, age 90 at the ground, about 1,000 cones, thousands of male inflor., 21 × 5, about 100 cones, in a 9 feet high *Salix* cfr *planifolia* thicket, 15 × 4, age 26 at the ground, about 100 cones, 7 × 2, no cones, in a dense *Betula glandulosa* and *Salix planifolia* thicket on *Hylocomium splendens* and *Equisetum arvense*, 7 × 2 on a similar ground vegetation, incl. *Mitella nuda, Cornus canadensis*, 5 × 1, in dense *Betula* thicket, 3 ½ × 1, on similar ground. All white spruces are wellgrown, without any sign of vegetative propagation.

There are 4 tamaracks: 13 × 3, half dead, no cones, 13 × 3, age about 90, no cones, 13 ½ × 3, about 48 years, no cones, in dense *Betula glandulosa* and *Ledum groenlandicum* thicket, 9 × 2, from the same root as the last one. All tamaracks, incl. the trees in the neighbourhood seem to have rot, and are more or less half dead.

The black spruce occurs only as large thickets: 1. bspr thicket about 15 square feet, with 26 vegetative shoots 1—9 feet high, offsprings from a larger stump. 2. bspr thicket with 18 vegetative shoots, some of these with double stems, 1—6 feet high, strongly intermingled among *Betula glandulosa, Ribes* cfr *glandulosum, Ledum groenlandicum*, on a thick *Sphagnum* cover. 3. minor bspr thicket with 4 vegetative shoots, in dense willow thicket, on the ground »muskeg» vegetation: *Rubus chamaemorus, Empetrum hermaphroditum, Sphagnum* ssp. 4. dense bspr thicket with 30 vegetative shoots, 1—8 feet high on an area of about 50 square feet, all from a stump of a candelabrum tree. Nearby a smaller

Fig. 26. Sketch map of permanent sample plot 39, about 36 × 51 feet (north upwards). The legend for white spruce, Betula glandulosa and Ledum groenlandicum is the same as on Fig. 22. The diagonally shaded areas indicate black spruce thickets, the numbers of the stems (vegetative propagation) in each thicket being indicated approximately. The dots are old (cut) trunks. The checkered areas to the right indicate four tamaracks. The white unmarked area is all covered with willow thicket. In the S part a wet Carex meadow.

Fig. 27. A ground section of a tamarack (about 100 years old, 21 feet high), immediately outside sample plot 29. Note the irregular growth (marks of larch saw-fly?) and the heart rot.

group of 3 vegetative shoots, 5 feet high. 5. bspr thicket of 8 vegetative shoots, 3—6 feet high, 6. bspr thicket with 13 vegetative shoots, 1—9 feet high on area of about 24 square feet, in a *Ledum groenlandicum-Salices* thicket, on the ground *Linnaea borealis, Mitella nuda, Cornus canadensis, Hylocomium splendens.* 7. depressed bspr thicket with 11 vegetative shoots, ½—2 ½ feet high in dense *Betula glandulosa-Salix planifolia* thicket. All bspr shoots without cones, bushy and developed from earlier cut trees; on the sample plot at least 113 vegetative shoots.

The growth of the terminal shoots of bspr offsprings appear from Table VII, where also some of the low wspr on the sample plot are included. In the years 1942, 1945 and especially in 1946 the terminal shoots seem often to have been damaged by frost or insect injuries, the terminal twigs are often broken in these years. The fairly rapid growth of the bspr twigs explains partly why they can compete with willows and dwarf birches on the sample plot.

Fig. 28. Vegetative propagation of black spruce on sample plot 39

This swampy sample plot shows the struggle between degenerating tamarack, active white spruce and black spruce, and especially the active response of black spruce to cutting in a swampy area. Fig. 28 shows the ordinary types of layering and thicket formation.

Cryptogams: feather mosses and Sphagna mixed: *Hylocomium splendens, Pleurozium Schreberi, Dicranum majus, Ptilidium ciliare, Aulacomnium palustre, Mnium* sp., *Brachythecium* sp., *Sphagnum Russowii, S. angustifolium* and *S. Girgensohnii.* Epiphyte lichens on spruce: *Ramalina Roesleri, Alectoria nidulifera, A. jubata, Parmelia sulcata.*

Reproduction: Only the reproduction described above.

40. A black spruce willow muskeg with tamaracks, about 10—11 miles inland from the HBC post. Under the trees vascular plants, usually belonging to drier habitats. Samples of trees: bspr 39 × 8 ½, age 148 (eccentric growth), 27 × 6 ½, age 87, 27 × 4 ½ age 61, tamaracks 30 × 5, age 79, 42 × 9, age 82; no cones on the tamaracks, few on the bspr. Nearby bspr reaches the size 45 × 10.

Cryptogams: dominant *Sphagnum* cover with scattered *Polytrichum* (cfr) *commune.*

Reproduction: no seedlings, because of the dense vegetation cover.

41. About 15—16 miles inland from the HBC post, about 150 feet above the river. A plain muskeg area with an old, fairly homogenous, stand of black spruce with no »group formation» or candelabrum trees, good pulpwood stand. The trees are branchless up to 12—15 feet above the ground, with fairly rich cone formation. Samples of trees: 27 × 5, age 145, 27 × 5, age 129, 27 × 4 ½, age 122.

Cryptogams: dominant *Sphagnum* cover, with scattered *Pleurozium Schreberi* and *Polytrichum* sp.

Reproduction: no seedlings, vegetative propagation on some trees.

42. Near sample plot 43, ½ mile N of the river, a black spruce muskeg about 110 feet above the river. This area is typical of the kind of forest which occurs on the burnt area, of which No. 43 is a sample plot. Fairly good pulpwood sized stand, some with double stems. Samples of trees: 30 × 6, age 107, 26 × 4, age 90, 24 × 5, age 134, 24 × 5, age 98, 18 × 3, age 91 at the ground. Few cones.

Cryptogams: dominant *Sphagnum* cover incl. *Hylocomium splendens* and *Pleurozium Schreberi.*

Reproduction: no notes.

43. About 100 feet lower down the slope from No. 42. This former muskeg area was burned, probably 11 years ago. Heavy thickets of *Betula glandulosa* and *Ledum groenlandicum* dominate the plot. No trees alive, the dead trees show a habitus often characteristic for black spruce on such localities,

Cryptogams: dominant *Sphagnum* cover and *Polytrichum commune*, scattered *Dicranum* sp. and *Nephroma* sp.

Reproduction: On the area, about 42×45 feet 38 bspr seedlings, most of them well grown. All seedlings were marked (permanent sample plot), their height $^1/_4$—2 $^1/_4$ feet and their age mostly 8—9 years, according to determination of the annual shoots. Just outside the permanent sample plot some seedlings were taken to control the age determination: 14×9 y, 12×9 y, 11 $\times 10$ y, 9×8 y, 7×8 y (height as usual above in inches). Some of the seedlings had double stems, some slightly damaged by frost 3rd of August. Terminal shoots are often glaucous on these wellgrown bspr seedlings, the secondary twigs, however, hairy. Growth of terminal shoots of the bspr seedlings on the sample plot is good. 1946 was a year with poor growth in this area. These seedlings are the best grown bspr seedlings seen in the area. The generative reproduction is thus fairly satisfactory on this sample plot which is near an unburned forest, see sample plot 42.

44. Balsam poplar grove on a S-slope on a mountain 15—16 miles inland from the HBC post, ½—1 mile S of the river. The sample plot is situated above the spruce forest limit and nearly forms a subalpine belt. Above this balsam poplar stand occurs only a scattered deformed *Viburnum edule* bush mixed with glandular dwarf birch. This is the only place where balsam poplar was seen by the author in the district. Samples of balsam poplars: 24×4, 21×6, 21×5, age about 55 on the ground.

Cryptogams: Dicranum fuscescens, Hylocomium pyrenaicum, Drepanocladus uncinatus, Brachythecium erythrorrhizum, all scattered or occasional only.

Reproduction: no seedlings, vegetative reproduction by balsam poplar. Note: *Actaea rubra* seems to closely follow the distribution of balsam poplar according to the author's notes from other balsam poplar groves in the Labrador Peninsula.

45. To show the usual character of an alder thicket in the area the following sample plot (noted by Mr. W. K. W. BALDWIN) is included. The sample plot is situated near Scotia Cove at Great Whale River, ½ mile from the sea, on the river shore, about 6 feet $\times$ 6 feet: common: *Alnus crispa, Salix* cfr *planifolia* and *Ribes glandulosum*, scattered: *Calamagrostis canadensis, Equisetum arvense, Solidago macrophylla*, occasional: *Heracleum lanatum, Trientalis borealis, Cornus canadensis* and *Epilobium angustifolium*. Moss cover: occasional *Brachythecium* sp.

*

Table IV gives a summary of the vascular plants on the sample plots 25—44.

Table IV. Vascular plants on sample plots 25—44.

	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
ium vitis-idæa . .	(1)[1]	(1)	—	—	×	1	×	×	1	2	—	2	2	—	×	—	—	—	×	—
inosum	—	—	—	1	×	1	—	—	×	—	—	—	×	2	—	2	2	2	1	—
ustifolium	—	—	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1
adense [2]	—	—	—	1	—	—	—	—	—	—	2	—	—	—	—	—	1	1	1	—
rum hermaphr.	×	(1)	—	1	×	1	1	×	1	—	×	2	2	×	2	2	1	1	—	—
concolor	×	—	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—
hloë alpina	×	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
illa tridentata . .	—	×	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
o sp.[3]	×	—	—	—	—	—	—	—	—	—	×	—	×	×	×	—	—	—	1	1
ium angust. . .	×	—	—	—	—	—	—	—	—	—	—	—	—	×	×	—	—	—	1	1
canadensis . .	—	—	1	—	×	1	1	×	1	1	1	—	—	×	×	1	—	×	1	1
glandulosa	—	—	1	—	2	—	—	—	1	2	2	3	2	3	2	1	—	1	3	—
groenlandicum	—	—	—	1	1	1	1	×	×	1	×	2	1	1	1	1	1	3	2	—
odium annot. . .	—	—	—	—	1	—	—	—	—	1	×	×	2	—	—	—	—	—	—	—
lis borealis	—	—	—	—	×	—	—	—	—	×	—	×	×	—	—	—	—	—	—	—
laris labradorica	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
mpsia flexuosa	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—
es palmatus . .	—	—	—	—	—	—	—	×	×	—	×	—	—	×	—	1	—	—	1	1
ium cespitosum	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	×	—	1	—
tum silvaticum	—	—	—	—	—	—	—	—	×	—	×	—	—	—	—	2	1	1	2	—
rus communis . .	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—
a borealis	—	—	—	—	—	—	—	—	—	1	—	×	1	×	×	×	—	—	—	1
dra livida	—	—	—	—	—	—	—	—	—	—	—	×	×	—	×	—	—	—	—	—
ıchier Bartram.	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	×
chamaemorus	—	—	—	—	—	—	—	—	—	—	—	1	—	—	×	2	3	3	1	—
crispa	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
aucuparia	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—
groenlandica . .	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—
ı polifolia	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	1	1	×	—	—
puniceus	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—
radula	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—
cespitosus . .	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—
illa fruticosa . .	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—
ja pallida	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—
ı alpina	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—
tum arvense . .	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
sp.[4]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	—	—	2	—
parviflora	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
nuda	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
ıgrostis sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
vaginata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
acaulis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
cus cfr microc.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—

Table IV (cont.)

	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Carex cfr brunnescens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C. stylosa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Actaea rubra	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Viburnum edule	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Viola sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fragaria virginiana ..	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Species	6	4	3	4	11	7	4	5	8	8	9	10	14	17	17	12	8	9

Note: 1. The brackets indicate that the species grows only under the tree crowns. 2. Or hairy form of Vaccinium angustifolium on plot 31. 3. On sample plot 25 Solidago multiradiata, on sample plots 43—44 S. macrophylla. 4. On sample plot 39 Salix obtusata and S. cfr pedicellaris, on sample plot 40 and 43 Salix pedicellaris and S. planifolia.

Part III.

8. Forest Types and Reproduction of the Forest.

In H 1949 an attempt was made to classify the forests on the Labrador Peninsula. The following tentative main forest types were distinguished:

A. Dry series:

1. conifer lichen forest,
2. conifer dwarf shrub-lichen forest,
3. conifer blueberry forest.

B. Moist series:

4. conifer feather moss forest,
5. conifer bunchberry (Cornus) forest,
6. rich conifer forest,
7. mixed groves.

C. Wet series:

8. open bog forest,
9. black spruce muskeg,
10. rich swamp forest.

The material for this classification was mainly the author's own limited experience from the vast Labrador forests. Included in this material were also the sample plots described above. The following summary shows the

commonest (tentative) forest types in the area covered in this paper. Figures in brackets refer to the sample plots 1—44. The signum (*A1*, *B4* etc.) refer to the main classification above.

A 1 a: Black spruce lichen forest, 27, 28.
A 1 b: White spruce lichen forest, 1, 2 (25), 26.
A 2 a: Black spruce dwarf shrub lichen forest, 5.
A 2 b: White spruce dwarf shrub lichen forest, 6, 29.
A 2 c: Jack pine Vaccinium lichen forest, 3, 4.
A 3 a: Black spruce blueberry forest, 35.
B 4 a: Black spruce feather moss forest, (8), 32, 33.
B 4 b: White spruce feather moss forest, 17—20.
B 4 c: Balsam fir feather moss forest, (16).
B 7: Balsam poplar groves, 24, 44.
C 9: Black spruce muskeg forest, 22, 40—42.
C 10 a: White spruce swamp (muskeg) forest, 21.
C 10 b: Tamarack swamp forest, 38.

The other sample plots represent more or less transition types or less clearly developed forest types; for instance, the »maritime transition forest», represented by sample plots 9—13, the white spruce-alder forest (14, 15) and the »white spruce-Vaccinium vitis-idaea forest» (34). The GWR area lies between the taiga proper and the forest-tundra which causes an impoverishment of forest types. Also, the situation of the area covered in this paper between the sea coast and the continental plateau of the interior makes the forest types mixed. The dominant forest types in the GWR area near the coast is the white spruce lichen forest (see Fig. 14) and the spruce dwarf shrub lichen forests. In the interior the black spruce lichen, black spruce dwarf shrub lichen, black spruce feather moss and black spruce muskeg forest types dominate, usually of good pulpwood size within some miles from the mouth of the river.

On the border zone between the treeless archipelago and the well wooded mainland S of GWR the forest types are still more difficult to point out. Most of the important taiga forest types occur here as »fragments» in the sheltered valleys. In the forest patches nearest to the sea shore, maritime elements intermingle with forest plants in the ground vegetation, and sometimes more or less arctic plants occur in the forests (9—13).

Is the forest on the coast advancing or retreating?

It was remarkable that old stumps of trees and decaying trees were fairly scarce in the coastal forest. One got the firm impression that the forest was

gradually occupying »new» land, especially on the sandy terraces and the elevated deltas on the shore of Hudson Bay N of Long Island Sound. Seedlings (white spruce particularly) occur near the outermost points of the maritime line. The rich cone production of white spruce was evident, at least in 1947. (In itself, rich cone production is, however, one of the general characteristics of the polar forest limit, compare RENVALL 1912 and H 1948; of importance is, of course, only the percentage of seeds which germinate.)

On p. 13 and 15 above the age of the white spruce and black spruce seedlings found near the maritime tree-line has been mentioned. The material is very limited as is also my material from the GWR area, see Table V. The uncertainty of the age determination of conifer seedlings on exposed localities must be stressed, compare H 1948. Table V should, therefore, be considered only as a very preliminary attempt; it shows, however, that seed years seem to occur almost annually. In the coastal area white spruce has more frequent seed years than black spruce. Many circumstances complicate the question. The possible dormancy of the spruce seeds during the summers after the cones have ripened is one of these unknown factors. (Regarding the dormancy of the Scotch pine seed in the northernmost Finland, compare RENVALL 1912). To build up a »seed year chronology» a very large amount of material would be needed, with every seedling carefully and microscopically determined as to its age. Particularly important in this respect is the easy formation of adventitious roots by black spruce. Also, the seed production changes according to the varying climate of the vegetation season. To establish an approximate seed year cycle for the northern forest is one of the important future projects in Canadian forestry, it forms the basis for forest management in vast areas where forest plantation must be excluded.

Table V. The age of some white spruce and black spruce seedlings from GWR.

Age:	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Wspr	1	1	2	7	2	7	5	1	6	4	3	3	4	3	3	2	2	1	3	—
Bspr	—	2	2	1	—	—	1	1	—	3	3	2	—	1	1	—	—	1	2	—

Age:	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Wspr	—	1	2	6	1	1	—	—	4[1]	1	—	2	—	1	—	—	1	1	3[2]
Bspr	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—

The general impression was that the generative reproduction in this area is satisfactory, i.e. in such forest types where generative reproduction normally

[1] = *about* 35 years; [2] = *about* 45 years.

occurs. This is, of course, not the case in the old feather moss forests (the climax forests of the taiga).

The scarceness of black spruce seedlings in the material also depends on the fact that the coastal region, with its white spruce dominance, was more closely studied. As appears from Table V, no seedlings younger than 7 years were found. All the seedlings included in the table are less than 3 feet high. The percentage of damaged seedlings in the lichen forests was great — the damage was mainly due to frost injuries. Chrysomyxa-infection was also noted in seedlings.

White spruce seedlings occur, as mentioned above and in Part I, also on the maritime tree line, just as far out as the outermost trees. Some white spruce seedlings on the maritime tree line N of GWR measured: 14×23 y (i.e. 14 inches high and 23 years old), 11×19 y, 7×12 y and 4×11 y.

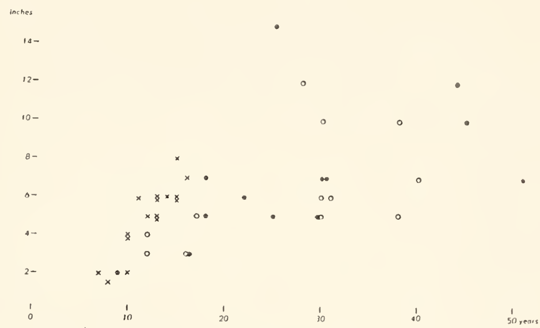


Diagram 2. The correlation age to length of white spruce seedlings from sample plots 25, 26 and 29. x=sample plot 25, white dots=sample plot 26, black dots=sample plot 29.

Diagram 2 shows the correlation between age and height of 41 white spruce seedlings on sample plots 25, 26 and 29. Note the difference between the fairly wellgrown and the »depressed» seedlings. The sample plots in Diagram 2 represent white spruce lichen and white spruce dwarf shrub lichen forests. Fig. 25 shows the germination of a spruce seedling in the furrows of a lichen cover, sample plot 29.

We return to our question: is the coast forest retreating or advancing? The fact that arctic-maritime elements intermingle with silvine elements in the ground vegetation in the coast forests is a fact which can hardly be used as evidence in one direction or the other. It is difficult to know if the arctic-maritime elements are actively penetrating the coast forest or if the silvine plants are penetrating towards the shore almost as fast as the trees. According to the author's impression, the later seems to be the case.

In northern Scandinavia there is ample evidence showing that the forest limit has been advancing towards the north in the last decades. Literature concerning this question is compiled in H 1948. The reason for this advance of the forest limit is the slight positive trend in the tempera-

ture in the northern parts of the temperate zone during the twenties and thirties.

The conditions in the GWR area and in northeastern Canada in general are more complicated. In the author's opinion, the scarce data regarding this question seem to point in the same direction as in northern Scandinavia, i. e. the forest has been slowly advancing in the last decades.

An important point is stressed by MARR. He states (1948, p. 143) that »trees grow on all areas of suitable soil (here used in the broad sense) regardless of exposure to atmospheric factors. Areas unsuitable for trees because of absence of soil are occupied by tundra. Trees are invading tundra areas as soil develops». MARR found in the Richmond Gulf area that the »potential climatic limit of forest under existing climate is an unknown distance north of the actual limit at the present time» (l.c., p. 144). Here, however, we must consider the fact that the Richmond area seems to be more favourable for forest growth because of its sedimentary bedrock than the surrounding country. Therefore, the contrast between forest and the barren country is probably more marked in the Richmond Gulf area than in other districts near the polar tree line on the Labrador Peninsula.

9. Tree Growth.

The annual variations in tree growth appear below in diagrams and in figures. The growth in thickness is easier to measure and also gives better results, whereas growth in height of a tree is more influenced by insect injuries, fungi, frost etc.

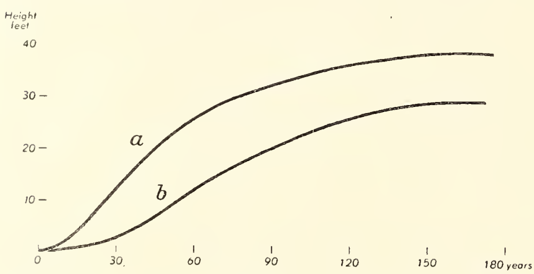


Diagram 3. The correlation age to height of spruce in the Great Whale River area. Based on 39 black spruce and 48 white spruce trees. No real difference between the two spruce species could be seen in the area; *a* = wellgrown spruce trees, *b* = poorly grown (though not depressed) spruce trees.

Growth in Height.

Diagram 3 gives a general picture of the growth in height of wellgrown and poorly grown spruce in the GWR area. There seems to be no particular difference between white and black spruce regarding growth in height in this area on ordinary forest types. The diagram is based on 39 black spruce and 48 white spruce trees. Dia-

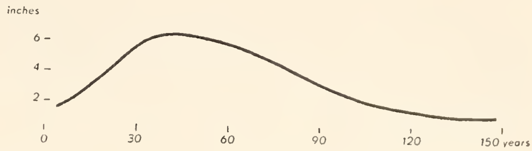


Diagram 4. An approximate graph of the correlation annual growth of length to age; black and white spruce in the lower part of the Great Whale River area.

gram 3 is very approximate and the age determinations are in most cases only based on the number of annual rings at 1.3 m above the ground. In poorer forest types one has to add at least 30 years to the »age» at DBH to get the approximate real age value. Diagram 3 is probably fairly representative of the poor tree growth in the northern parts of the taiga.

Diagram 4 gives an idea of the annual growth in height of spruce in different age stages in the GWR area.

Table VI illustrates the growth in height of 4 trees during the period 1935—47. Trees No. 1—3 are from spruce dwarf shrub lichen forest, near sample plot 29, tree No. 4 is from a muskeg near sample plot 39. According to Table VI 1937 was a year with poor growth in height in this district, 1936 a year with good growth in height. The growth in height is usually interrupted by frost damage, fungi and insect injuries.

Table VI. Growth in height of spruces (annual increment in cm).

Tree	Age	Height (feet)	1947	46	45	44	43	42	41	40	39	38	37	36	35
1. wspr	150	30	2	2	3	3	3	3	4	3	3.5	2.5	2	2.5	2
2. wspr	125	25 ½	2.5	3	4	4	3	2	4	3.5	6	5	2.5	3.5	3.5
3. bspr	95	31	2	4	9	8	7	9	8	7	7	7	3	6	—
4. wspr	90	30	5	13	10	7.5	11	16	21	20	20	15	13	13	—

Table VII. Growth of old spruce seedlings in height, 1940—1947.

Height (feet)	Growth in cm in:							
	1947	46	45	44	43	42	41	40
7 (wspr)	9	6	12	15	15	15	13	13
6 (bspr)	11	5	11	12	9	3.5	4	6.5
6 (wspr)	7	3.5	6	8.5	8	5	—	—
5 ½ (bspr)	13	11	12	15	12	12	13.5	10
5 (bspr)	8	5	4	3	5	7	7.5	5.5
4 (bspr)	4.5	3	10	10	10	7	—	—
3 ½ (wspr)	1.5	1.5	3	3.5	6	6	7.5	8.5
3 (bspr)	7	4	8	7	2	2.5	—	—

In Tables VII and VIII some figures are given concerning the growth in height of younger spruce trees and seedlings. In Table VII the annual increment in height of black spruce shoots and white spruces from sample plot 39 show a marked minimum year in 1946.

In Table VIII the annual increment of 3 white spruce and 7 black spruce seedlings show the minimum years 1937 and 1946, mentioned above. Note also the relation between age and height; compare also Diagram 2.

Table VIII. Growth of spruce seedlings 1936—1947.

Seedling	Heigth (feet)	Age	Growth in cm in:											
			1947	46	45	44	43	42	41	40	39	38	37	36
1. wspr	6	65	2	4	6	6	6.5	3.5	4	4.5	6	6	3	5
2. wspr	5	60	2.5	4	4	4	3.5	3	3	3.2	6	7	3	4.5
3. bspr	4 ½	18	22	9	20	14	9	4	8.5	—	—	—	—	—
4. bspr	4	16	6	7	16	16	15	12	10	10	8	4	—	—
5. bspr	3 ¼	16	17	6	8	5	9	7	7	—	—	—	—	—
6. wspr	3	50	1	1	1	1	1.5	1.6	1.4	1.5	1.6	2.3	2	1.4
7. bspr	5	25	2	4	9	8	7	8.5	7.5	7	7	7	3	5
8. bspr	3	42	8	5	8	9	7	6	3	—	—	—	—	—
9. bspr	3	16	16	9	9	9	8	6	6	—	—	—	—	—
10. bspr	21/4	24	12	3	4	3.5	7	5	5	4	—	—	—	—

Table VIII shows the great difference between seedlings on different habitats. Seedlings 1, 2, 6 and 7 are from a lichen heath near sample plot 29, i.e. fairly near the coast. These seedlings (1, 2, 6) are depressed, whereas the seedlings 3—5, 8—10 are well developed and in part unusually fast growing, on a lichen heath about 15 miles inland.

In the northern parts of the boreal forest region the growth in height seems to reach its maximum in the year *after* a favourable summer. Above, the years 1937 and 1946 represent fairly marked »minimum» years. From Table X it appears that 1936 and 1945 were marked minimum years in the growth in thickness. In this respect the northern spruce reacts in exactly the same way as the Scotch pine in the north (H 1938). In southern arid regions, however, growth in thickness and growth in length seem to coincide, i.e. if the summer is favourable, growth in thickness and growth in length reach their maximum in the same year.

Growth in Thickness.

The radial growth, i.e. the growth in thickness, gives a better picture of the general variations in the growth of a tree from one year to another than

the growth in length. The radial growth measurements are also useful in judging the quality of different habitats and sites.

The growth in thickness is influenced mainly by the amount of precipitation and the temperature. In arid regions the precipitation is the more important factor, in the north, however, the temperature. This fact has been stressed by many authors in Scandinavia and in Finland, and in North America. GIDDINGS proved this statement with material from Alaska (1941) and Mackenzie River (1947). At GWR the radial growth is probably mainly influenced by the temperature in July and in the beginning of August, i.e. the short period with cambial activity in the northernmost forests. Thus, Tables X and XI also give an idea of the annual variations of the summer temperature in the last 100—175 years in the GWR area.

The material consists of increment cores taken from trees described above in connection with the sample plots. Some of the cores were useless, broken, or showing growth disturbed by insects or fungi, or an abnormal change of the site. Only increment cores taken at breast height, from the south side of the tree, are used in the tables. They are arranged according to the forest type; only sample plots represented by at least two good cores are included in the tables below. No cores of tamarack could be used, because tamarack is more sensitive to attacks by insects or fungi, which cause needle fall in the middle of the growth season. This results in more or less total interruption of cambial activity. Fig. 27 shows a section of a tamarack whose very irregular growth patterns are typical of this species in the GWR area. For dendrochronological purposes tamarack seems to be completely useless, compare also MARR (1948), pioneer dendrochronologist in this unknown area.

The increment cores were obtained with a Swedish increment borer. Only one core was taken from each tree. This is, of course, not entirely satisfactory from a dendrochronological point of view, compare GLOCK 1941. But when the observer has some experience and himself selects the trees in the field, this simple method should be useful for a preliminary survey of the growth conditions in an area fairly unknown. MARR, who himself partly follows another method, see below, states, however: »a single core taken at any point, gives an accurate representation of the relative width of the growth layers in trees in this (GWR) region» (1948, p. 139).

The width of the annual rings was measured, using a new apparatus constructed by the Swedish forest scientist, Dr BO EKLUND. One of these machines has been bought by the Forest Research Institute in Helsingfors. The measurements were carefully taken by Mr. FRITZ BERGMAN, himself a forest student. The annual ring was measured to an accuracy of 0.01 mm. This

accuracy is necessary when measuring the slowly growing spruce at its northern limit.

Table IX gives a presentation of the 44 trees used in Table VI, their height, age and diameter according to field notes and the length of the radius according to measurements on air-dried cores. In Table X the series indicate average values of 2—6 trees, each series representing one sample plot only. The same values are plotted on Diagrams 5—7 which clearly show the great annual variations in radial growth in the GWR area. The variation coefficient in such growth series increases towards the north, where the »climatic hazard coefficient» is greater than in southern parts of the boreal forest region, compare H 1948.

Apart from the fact that the series in Table X indicate average values of 2—6 trees, *no »manipulation», »correction» or »smoothing» has been made.* The good correlation between the different series and between the annual variations in growth on different forest types is therefore striking. In the opinion of the author this fact indicates that the simple method used here can give a fairly correct impression of the *annual* variations in tree growth. It must also be stressed that the series given by MARR in his paper (1948) and the series in Tables X—XVII coincide well.

Due to factors beyond his control the author happened to make his studies in 1947 in one of the two districts in which MARR 1939 carried out his dendrochronological work (published in 1948). However, our studies are made from different viewpoints. MARR follows the same lines as were developed by the Arizona school of dendrochronology, see GLOCK 1937. His »master chart» from GWR is reproduced here, in connection with Diagram 6—7. MARR's master chart is based on 9 trees, all from the same forest type, the white spruce-lichen forest on the elevated delta at the mouth of GWR. From each tree Marr took four cores which were not measured in detail; here — unfortunately — the »more rapid reading technique developed by Douglass and fully described by Glock (1937) was used» (l.c., p. 133). Marr, however, also carefully measured sections of dissected white spruce trees from GWR; one of these is graphically shown in his paper (p. 134). Marr's work is the first of its kind from NE-Canada, and he therefore takes the trouble to give a detailed description of tree growth patterns in the north. He sums up some basic facts, well-known also to investigators of the growth in the northernmost forests of Scandinavia. He states, for instance, that examination of the »three dissected trees revealed not a single instance of a layer that was circumferentially incomplete. — Completeness of growth rings is certainly the very general rule for trees in good soils in this region» (l.c., p. 139). However, in depressed seedlings and

in young trees incomplete layers can occasionally be found. It is, thus, a good rule in tree ring work to avoid the use of the innermost rings in a core or a section.

The author's method is different. He uses only one increment core from each tree, but this core, always taken from the south side at breast height above the ground, has been carefully measured. The 44 trees in Table X *represent ordinary, dominant forest types in the area*. Nevertheless, the material is too inadequate to give more than an approximate dendrochronological series. Because such series are still very scarce from the northern forests in Canada, it can, perhaps, be of some use for forest scientists interested in growth patterns.

*

The *extremely slow growth* of black spruce is clearly seen in Table X. Note, for instance, that the old black spruces included in series 30 and 42 have an average annual tree ring width of about 0.2 mm. One of the trees in series 30 showed in 195 years an annual average growth of 0.26 mm only, and in the last 175 years an average annual tree ring width of 0.19 mm. This slow growth of black spruce is a well-known fact to foresters, but it is probably less well known that the white spruce also attains such slow growth on lichen heaths; compare Fig. 16. This slow growth in thickness in the dominant forest types in the north produces a good pulpwood. This is, however, combined with an extremely slow rotation in the forests.

Also of interest in Table X is the unusual good growth of black spruce on sample plot 27, a lichen heath. My first impression of these lichen covered spruces was that they were very old; the increment borer showed, however, a remarkably good growth in exposed conditions.

Some of the older series show a slight increase in the radial growth in the last decades, note the remarks above regarding the possible advance of the polar tree line. This increase in radial growth is, however, not as evident as, for instance, the marked increase in the radial growth of pine in the northernmost areas of Scandinavia (H 1948). This is probably due to the fact that the length of the day in the relative southern latitude of the GWR area does not influence or rather increase the effect of the slight positive trend in the temperature as much as the long day at 70° northern Lat.

In Table X only trees from GWR are included. The material in Table XI is not as homogenous as in Table X, it consists of cores from trees along the maritime tree-line on the coastal zone, i.e. trees from sample plots 1—21. In Table XI as in Table X the series are mean values of some trees from different

Table IX. Trees included in Table X.

Sample plot	Tree	Age (BH)	Height (feet)	DBH (inches)	Radius (airdried core, cm) at breast height
25.	wspr	54	21	6	5.0
	»	53	23	8	11.1 (1½ feet above the ground
26.	»	52	24	3½	3.5
	»	54	23	3½	3.3
	»	55	21	3	2.2
	»	75	30	6½	6.3
27.	bspr	30	24	6	4.6
	»	25	21	4	3.2
	»	23	18	3½	3.0
29.	wspr	105	33	8	8.6
	»	105	26	4	5.1
	»	100	30	8	7.5
	»	72	24	4	4.0
	»	83	27	5	6.0
	»	65	23	4½	5.7
30.	bspr	190	39	6	6.5
	»	180	27	4	5.1
	»	185	39	8½	7.4
31.	»	165	39	9	8.3
	»	171	42	8½	8.6
	»	160	42	8	6.9
32.	»	125	36	10	10
	»	84	27	5	5.6
	»	78	36	8	7.2
33.	»	74	27	6½	5.6
	»	87	36	7	7.4
34.	wspr	82	36	8	8.6
	»	80	33	6	6.5
	»	71	27	4	4.8
	»	77	33	6½	7.7
35.	bspr	80	24	6	7.0
	»	90	21	6½	7.5
37.	wspr	100?	18	6	6.0
	»	155	27	8½	8.5
	bspr	75	21	4	4.0
	»	47	23	4½	4.2
40.	»	87	27	6½	7.8
	»	61	27	4½	3.8
41.	»	129	27	5	4.8
	»	122	27	4½	4.0
	»	145	27	5	5.2
42.	»	134	24	6	6.2
	»	107	30	6	6.2
	»	90	26	4	4.3

Table X. Radial growth series from Great Whale River, 1847—1946.

	White spruce					Black spruce									
Sample plot	25	26	29	34	37	27	30	31	32	33	35	37	40	41	42
Number of trees	2	4	6	4	2	3	3	3	3	2	2	2	2	3	3
1946	122	45	39	66	26	135	26	21	50	34	52	70	76	24	37
1945	101	36	44	63	27	123	22	42	43	23	56	73	70	24	40
1944	115	42	47	63	26	144	22	22	46	32	62	74	66	24	39
1943	120	42	40	67	26	108	21	22	43	33	53	74	67	23	36
1942	137	48	46	80	29	143	22	26	45	35	54	83	68	26	35
1941	150	51	54	97	27	150	22	24	55	36	59	96	62	29	39
1940	109	44	44	83	22	111	15	18	40	29	46	63	47	19	23
1939	135	42	45	86	25	109	19	22	51	33	53	74	58	24	21
1938	150	53	47	84	30	111	19	24	67	43	65	76	68	27	19
1937	130	52	48	76	31	111	21	25	65	38	58	62	65	26	23
1936	95	45	35	58	24	115	18	22	55	34	50	62	57	23	23
1935	175	63	56	64	32	119	21	31	61	45	60	88	76	30	34
1934	98	45	44	69	31	115	20	30	50	31	51	57	53	27	28
1933	96	45	50	68	28	146	19	26	46	28	45	61	50	21	27
1932	113	50	54	67	25	178	23	30	44	33	52	72	42	22	30
1931	147	45	51	70	19	161	21	29	50	40	74	56	41	26	33
1930	114	49	62	71	26	138	19	28	50	43	65	48	43	26	39
1929	93	39	46	50	16	143	19	25	43	41	65	38	40	20	31
1928	162	54	59	80	32	185	22	30	60	58	78	58	53	30	43
1927	102	40	39	58	22	139	21	28	48	54	59	42	45	25	26
1926	98	51	48	58	22	135	17	18	45	44	59	37	43	22	30
1925	101	49	52	66	23	—	20	21	62	50	66	56	51	22	34
1924	126	54	62	82	28	—	24	26	67	67	80	55	58	24	39
1923	184	58	67	94	31	—	27	23	71	94	41	41	61	31	38
1922	195	59	55	87	30	—	24	21	63	48	88	40	63	22	31
1921	217	59	67	79	28	—	27	21	68	58	98	48	68	32	31
1920	197	42	56	61	27	—	20	19	69	41	93	35	64	29	27
1919	235	63	72	79	34	—	25	23	68	56	97	48	74	29	34
1918	203	54	60	79	29	—	25	21	64	40	80	58	72	25	29
1917	231	57	69	99	29	—	28	25	78	44	95	76	75	31	30
1916	232	55	64	74	27	—	23	21	81	46	92	51	74	30	24
1915	175	39	55	54	20	—	22	19	64	38	85	40	66	25	21
1914	148	47	52	58	19	—	28	21	83	61	119	45	72	28	22
1913	175	54	58	61	25	—	26	19	85	64	123	68	88	24	24
1912	145	50	45	50	20	—	22	18	77	43	96	54	62	20	19
1911	212	71	64	76	30	—	34	27	106	71	132	93	97	30	28
1910	233	63	63	62	24	—	28	23	95	68	135	98	113	25	26
1909	180	54	57	64	24	—	24	21	78	65	129	62	90	22	18

Table X (cont.)

Sample plot	White spruce					Black spruce									
	25	26	29	34	37	27	30	31	32	33	35	37	40	41	42
Number of trees	2	4	6	4	2	3	3	3	3	2	2	2	2	3	3
1908	193	58	65	68	29	—	21	24	71	61	132	57	75	19	19
1907	—	92	84	78	34	—	23	24	73	68	139	65	76	21	21
1906	—	95	84	84	40	—	23	29	78	72	132	73	82	23	23
1905	—	88	80	72	39	—	25	26	77	73	118	71	80	22	19
1904	—	122	89	96	41	—	22	27	79	71	121	75	93	27	23
1903	—	132	100	106	48	—	22	29	77	73	123	86	93	33	24
1902	—	101	70	80	46	—	22	27	72	56	105	86	85	28	22
1901	—	137	90	103	61	—	20	29	85	70	112	99	108	29	21
1900	—	100	85	96	56	—	20	28	84	78	108	91	95	28	20
1899	—	—	75	81	42	—	19	28	77	76	119	83	77	25	18
1898	—	—	76	102	42	—	16	30	80	73	126	85	77	24	20
1897	—	—	85	102	56	—	19	33	86	103	119	94	88	29	25
1896	—	—	78	110	69	—	18	34	87	89	102	—	100	27	24
1895	—	—	95	139	67	—	19	36	96	88	122	—	110	29	28
1894	—	—	90	129	58	—	18	30	68	72	95	—	—	28	24
1893	—	—	93	118	55	—	18	34	73	84	93	—	—	34	27
1892	—	—	82	95	61	—	15	32	67	82	90	—	—	30	26
1891	—	—	80	93	69	—	17	37	79	78	100	—	—	25	28
1890	—	—	81	112	71	—	16	36	80	80	105	—	—	29	29
1889	—	—	65	111	59	—	12	33	66	78	101	—	—	22	26
1888	—	—	61	143	54	—	15	40	83	82	102	—	—	28	29
1887	—	—	64	125	62	—	21	52	96	92	105	—	—	39	39
1886	—	—	53	122	50	—	19	48	87	77	96	—	—	33	40
1885	—	—	47	122	57	—	20	47	—	95	95	—	—	34	44
1884	—	—	48	89	63	—	19	54	—	97	96	—	—	44	45
1883	—	—	52	101	53	—	20	48	—	79	97	—	—	36	47
1882	—	—	63	—	68	—	21	51	—	101	96	—	—	40	49
1881	—	—	66	—	74	—	22	51	—	111	111	—	—	46	59
1880	—	—	85	—	113	—	21	50	—	109	90	—	—	49	62
1879	—	—	73	—	63	—	21	40	—	98	90	—	—	43	56
1878	—	—	91	—	61	—	20	48	—	85	—	—	—	39	55
1877	—	—	101	—	63	—	18	38	—	59	—	—	—	37	56
1876	—	—	90	—	65	—	15	38	—	66	—	—	—	31	51
1875	—	—	83	—	86	—	16	38	—	73	—	—	—	34	57
1874	—	—	86	—	91	—	22	55	—	97	—	—	—	43	72
1873	—	—	79	—	70	—	24	59	—	100	—	—	—	59	80
1872	—	—	71	—	85	—	23	47	—	85	—	—	—	50	34
1871	—	—	61	—	73	—	21	39	—	—	—	—	—	41	33

Table X (cont).

Sample plot	White spruce					Black spruce									
	25	26	29	34	37	27	30	31	32	33	35	37	40	41	42
Number of trees	2	4	6	4	2	3	3	3	3	2	2	2	2	3	3
1870	—	—	74	—	81	—	24	50	—	—	—	—	—	50	46
1869	—	—	43	—	73	—	17	35	—	—	—	—	—	34	21
1868	—	—	81	—	—	—	20	49	—	—	—	—	—	46	35
1867	—	—	73	—	—	—	20	47	—	—	—	—	—	46	35
1866	—	—	66	—	—	—	16	41	—	—	—	—	—	34	36
1865	—	—	85	—	—	—	21	51	—	—	—	—	—	45	49
1864	—	—	66	—	—	—	25	51	—	—	—	—	—	44	53
1863	—	—	77	—	—	—	22	46	—	—	—	—	—	46	57
1862	—	—	79	—	—	—	19	46	—	—	—	—	—	35	63
1861	—	—	98	—	—	—	23	54	—	—	—	—	—	57	101
1860	—	—	82	—	—	—	24	42	—	—	—	—	—	48	73
1859	—	—	83	—	—	—	23	40	—	—	—	—	—	47	73
1858	—	—	111	—	—	—	21	39	—	—	—	—	—	53	75
1857	—	—	101	—	—	—	17	36	—	—	—	—	—	48	52
1856	—	—	89	—	—	—	18	43	—	—	—	—	—	50	56
1855	—	—	81	—	—	—	20	42	—	—	—	—	—	43	46
1854	—	—	90	—	—	—	18	46	—	—	—	—	—	45	57
1853	—	—	101	—	—	—	21	45	—	—	—	—	—	57	54
1852	—	—	82	—	—	—	21	46	—	—	—	—	—	48	39
1851	—	—	87	—	—	—	25	49	—	—	—	—	—	—	67
1850	—	—	92	—	—	—	25	48	—	—	—	—	—	—	64
1849	—	—	81	—	—	—	22	45	—	—	—	—	—	—	56
1848	—	—	84	—	—	—	20	40	—	—	—	—	—	—	33
1847	—	—	60	—	—	—	20	31	—	—	—	—	—	—	27

Note: Series 29: 2 trees 1847—56, 3 trees 1857—77, 4 trees 1878—86, 6 trees 1887—1946; Series 39: 1872—92, 1 tree; Series 42: 1846—76, 1 tree.

forest types; each series, thus, represents a forest type unit. Usually collectors of dendrochronological material take their cores from very old trees, growing in extreme climatic or edaphic conditions. Here the trees measured represent more or less normal trees in the forest. The average width of the annual rings thus, perhaps, also represent the growth capacity of the most important forest types in the area covered by the investigation.

When comparing Tables X and XI the better growth in thickness of the series from the maritime tree-line is evident. White spruce is more common

Table XI. Radial growth series from sample plots 1—21 in Table II.

Sample plot	White spruce:															bspr		bfir
	1	6	9	10	11	12	13 a	13 b	14	15	17	18	19	20	21	5	8	16
Number of trees	2	2	3	4	4	2	3	2	2	3	3	3	3	3	2	3	3	3
1946	22	61	111	91	64	35	63	107	86	107	68	49	53	65	18	64	63	110
1945	16	74	130	83	55	30	61	108	79	103	71	40	52	61	15	53	43	77
1944	24	83	144	131	72	50	56	118	95	103	83	37	61	76	21	66	48	94
1943	21	74	111	123	76	50	53	60	89	130	87	40	63	66	18	69	55	102
1942	25	61	117	132	80	52	73	84	95	138	99	39	55	73	18	70	61	111
1941	35	61	117	141	82	50	80	89	95	141	117	30	44	90	24	73	70	102
1940	25	53	124	151	62	37	54	94	85	108	106	34	37	66	16	60	52	89
1939	30	56	97	142	70	50	72	92	75	89	137	46	34	69	17	82	59	94
1938	28	55	108	166	76	47	77	96	80	87	138	40	36	84	18	77	62	71
1937	23	77	134	181	86	42	73	99	98	105	134	47	35	78	23	65	61	58
1936	12	59	150	185	46	30	46	62	56	62	102	39	36	54	14	60	53	67
1935	20	77	157	188	87	59	65	89	85	96	161	57	40	70	26	83	83	67
1934	16	64	139	154	68	40	55	55	58	101	97	48	38	54	18	70	70	59
1933	22	67	142	185	69	49	75	63	73	96	122	44	35	79	32	75	67	68
1932	22	81	173	153	68	40	60	67	70	107	109	49	42	70	28	76	84	63
1931	32	81	172	148	85	54	54	68	55	88	145	47	42	102	36	64	77	64
1930	36	84	144	179	88	52	60	62	75	83	141	49	41	115	44	58	83	67
1929	33	78	126	147	76	30	43	54	50	86	116	40	39	81	30	57	83	60
1928	46	89	125	149	98	52	38	66	68	109	149	52	53	107	36	66	101	81
1927	27	62	151	146	74	32	54	53	68	100	109	43	38	69	21	49	88	69
1926	35	68	144	174	88	34	47	53	75	98	114	38	34	74	28	44	75	75
1925	30	56	130	145	73	29	44	—	66	102	130	39	35	69	27	37	82	74
1924	43	69	135	154	86	44	62	—	93	109	155	49	47	81	39	45	82	84
1923	51	100	126	166	98	57	63	—	92	156	161	58	45	82	43	47	99	74

1922	40	90	152	125	96	36	64	—	94	123	139	49	42	80	25	42	114	85
1921	40	104	163	143	97	45	72	—	168	109	153	48	45	85	37	48	102	74
1920	31	94	149	197	86	29	85	—	145	101	144	48	37	68	34	47	101	79
1919	51	132	179	202	125	55	134	—	231	129	201	62	39	94	45	58	109	104
1918	32	114	158	184	92	35	112	—	165	125	172	54	33	80	32	52	107	89
1917	41	133	147	186	75	46	104	—	144	109	227	59	31	89	49	51	97	85
1916	49	110	116	165	83	41	81	—	200	122	238	44	34	97	54	40	106	93
1915	42	102	121	198	62	33	82	—	164	114	194	44	30	71	42	38	121	95
1914	50	109	110	186	72	46	66	—	149	96	193	48	30	75	49	36	123	138
1913	51	89	107	227	71	33	84	—	186	107	185	52	31	84	48	34	145	143
1912	35	100	105	200	55	26	69	—	131	90	—	41	25	77	36	35	108	130
1911	60	140	121	231	80	66	99	—	189	112	—	52	35	143	61	56	152	165
1910	34	153	145	201	66	45	94	—	204	119	—	49	43	119	55	50	165	158
1909	57	115	127	186	70	35	77	—	181	97	—	45	33	115	54	44	140	147
1908	92	154	117	197	84	40	102	—	237	111	—	54	41	116	58	47	149	175
1907	87	170	137	155	84	32	90	—	175	108	—	53	46	105	62	45	150	182
1906	80	185	108	159	88	46	131	—	210	144	—	51	58	93	80	49	170	221
1905	62	150	97	137	73	40	113	—	190	129	—	54	57	80	56	45	191	217
1904	82	172	119	196	96	51	134	—	234	200	—	65	70	115	70	47	218	305
1903	80	182	158	174	93	52	114	—	204	177	—	68	90	107	75	60	198	241
1902	63	198	129	114	71	44	111	—	128	161	—	65	72	72	51	50	190	220
1901	91	190	130	154	74	64	76	—	175	165	—	64	85	87	77	57	195	224
1900	82	168	153	168	61	66	70	—	156	147	—	56	84	65	65	61	198	172
1899	62	—	183	195	68	52	91	—	117	161	—	61	80	58	57	60	207	188
1898	65	—	185	167	68	59	105	—	127	138	—	63	44	68	71	64	195	179
1897	63	—	157	126	74	70	75	—	148	146	—	66	52	62	76	70	179	144
1896	115	—	136	179	110	62	87	—	199	213	—	60	52	82	80	73	232	162
1895	119	—	160	170	99	72	112	—	161	206	—	61	48	70	81	68	243	157
1894	94	—	—	195	80	51	72	—	136	187	—	57	47	66	63	73	214	102
1893	89	—	—	206	82	58	80	—	162	183	—	47	38	70	71	63	200	144
1892	109	—	—	137	91	55	126	—	190	176	—	41	36	71	91	63	226	157

Table XI (cont.)

Sample plot	White spruce:															bspr		bfir
	1	6	9	10	11	12	13 a	13 b	14	15	17	18	19	20	21	5	8	16
Number of trees	2	2	3	4	4	2	3	2	2	3	3	3	3	3	2	3	3	3
1891	91	—	—	106	86	47	82	—	152	186	—	39	39	57	97	54	242	126
1890	100	—	—	—	92	52	94	—	138	—	—	51	48	88	111	66	205	104
1889	93	—	—	—	84	50	118	—	129	—	—	69	56	93	102	77	223	136
1888	84	—	—	—	81	42	119	—	123	—	—	84	61	101	92	80	197	153
1887	109	—	—	—	91	62	125	—	160	—	—	107	69	135	130	85	211	186
1886	102	—	—	—	104	45	131	—	142	—	—	100	60	108	95	52	204	207
1885	123	—	—	—	100	63	147	—	104	—	—	118	64	135	101	59	194	173
1884	75	—	—	—	98	66	153	—	116	—	—	146	67	82	81	51	202	178
1883	—	—	—	—	115	60	143	—	152	—	—	142	78	72	78	89	—	196
1882	—	—	—	—	96	80	116	—	93	—	—	169	91	95	89	89	—	206
1881	—	—	—	—	122	75	144	—	118	—	—	170	98	105	86	66	—	173
1880	—	—	—	—	111	68	177	—	151	—	—	150	101	116	101	68	—	121
1879	—	—	—	—	96	42	157	—	205	—	—	138	84	73	84	91	—	133
1878	—	—	—	—	120	71	181	—	224	—	—	135	93	95	112	99	—	147
1877	—	—	—	—	120	66	117	—	178	—	—	—	89	100	128	99	—	101
1876	—	—	—	—	113	52	—	—	227	—	—	—	88	127	157	79	—	112
1875	—	—	—	—	64	49	—	—	192	—	—	—	92	118	132	76	—	158
1874	—	—	—	—	89	56	—	—	159	—	—	—	104	111	122	93	—	151
1873	—	—	—	—	36	45	—	—	249	—	—	—	111	102	114	117	—	134
1872	—	—	—	—	50	45	—	—	221	—	—	—	118	76	105	121	—	121
1871	—	—	—	—	62	30	—	—	187	—	—	—	83	66	91	138	—	128
1870	—	—	—	—	62	50	—	—	214	—	—	—	113	125	137	131	—	136
1869	—	—	—	—	67	41	—	—	99	—	—	—	75	119	78	118	—	124
1868	—	—	—	—	79	60	—	—	130	—	—	—	105	89	144	180	—	111

1867	—	—	—	—	65	68	—	—	149	—	—	—	105	111	160	180	—	121
1866	—	—	—	—	72	33	—	—	145	—	—	—	86	72	109	161	—	89
1865	—	—	—	—	60	51	—	—	108	—	—	—	80	90	141	131	—	70
1864	—	—	—	—	64	48	—	—	171	—	—	—	79	93	122	105	—	57
1863	—	—	—	—	71	56	—	—	200	—	—	—	87	99	131	108	—	53
1862	—	—	—	—	76	59	—	—	179	—	—	—	77	107	156	97	—	47
1861	—	—	—	—	64	75	—	—	183	—	—	—	79	113	174	113	—	46
1860	—	—	—	—	60	60	—	—	—	—	—	—	77	103	158	—	—	40
1859	—	—	—	—	60	66	—	—	—	—	—	—	82	61	141	—	—	39
1858	—	—	—	—	54	96	—	—	—	—	—	—	86	91	180	—	—	32
1857	—	—	—	—	91	111	—	—	—	—	—	—	97	74	134	—	—	32
1856	—	—	—	—	73	109	—	—	—	—	—	—	99	96	148	—	—	39
1855	—	—	—	—	82	80	—	—	—	—	—	—	77	123	126	—	—	42
1854	—	—	—	—	103	107	—	—	—	—	—	—	96	159	159	—	—	38
1853	—	—	—	—	75	104	—	—	—	—	—	—	82	109	185	—	—	36
1852	—	—	—	—	78	86	—	—	—	—	—	—	86	106	147	—	—	49
1851	—	—	—	—	52	94	—	—	—	—	—	—	73	104	132	—	—	44
1850	—	—	—	—	58	86	—	—	—	—	—	—	70	102	144	—	—	40
1849	—	—	—	—	49	69	—	—	—	—	—	—	65	128	126	—	—	27
1848	—	—	—	—	49	59	—	—	—	—	—	—	53	98	105	—	—	31
1847	—	—	—	—	59	48	—	—	—	—	—	—	84	97	72	—	—	27

Note to Table XI: The trees included in the radial growth series are mentioned above in connection with the sample plots. Because of the different age of the trees included in some series especially the earlier parts of the series are uncertain. Series (sample plot) No. 10 includes 1 tree during the period 1891—1903, 2 trees 1904—07, 3 trees 1908—20, 4 trees 1921—46. Series No. 11 includes 1 tree 1847—75, 2 trees 1876—1918, 4 trees 1919—46. Series No. 12 includes 1 tree 1847—84, 2 trees 1885—1946. Series No. 13 a includes 1 tree 1877—98, 2 trees 1899—1903, 3 trees 1904—46. Series No. 19 includes 2 trees 1847—71, 3 trees 1872—1946. Series nr 20 1 tree 1847—46, 2 trees 1847—1946. Series No. 5 (black spruce) includes 1 tree 1861—81, 2 trees 1882—1946. The balsam fir series includes 1 tree 1847—75, 2 trees 1876—1904, 3 trees 1905—1946.

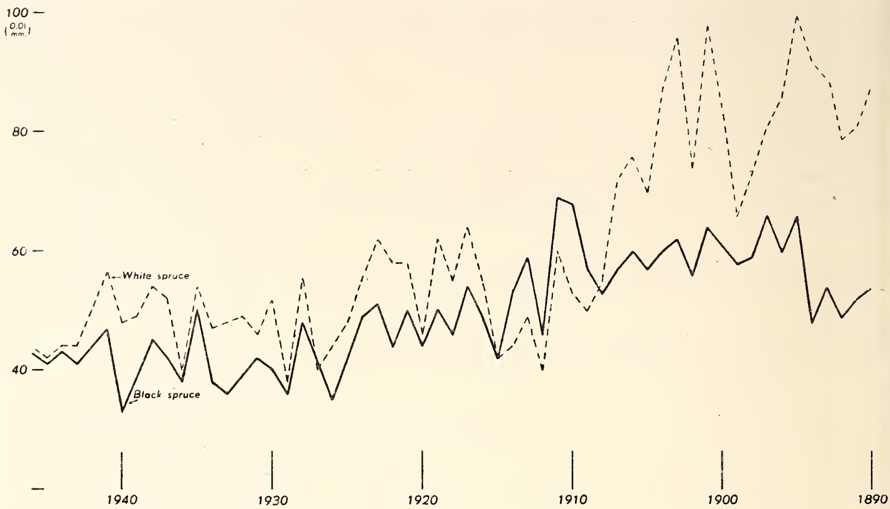


Diagram 5. The radial growth of white and black spruce in the GWR area; compare Tables XII and XIII. Note the good correlation between the two spruce species.

in the coastal zone and it therefore also dominates Table XI. The good growth in thickness of the white spruce trees at the maritime tree-line is probably due to the increased cambial activity caused by the wind on exposed localities. The short jack pine series, see p. 26, is omitted from Table XI.

In Tables X and XI 94 trees are represented. The material is, thus, fairly small. However, also a small but in the field selected and carefully measured material can show the dendrochronological main features in an area. It also illustrates the general growth pattern of the trees and indicates certain growth cycles and the most prominent »minimum» years in the last century.

It is of interest to compare Marr's »master chart» with the series in Tables X and XI. Before this is done, the material is divided into 6 series: Table XII shows the radial growth of white spruce in the GWR area (16 trees from sample plots 26, 29, 34 and 37) 1890—1946, Table XIII the radial growth of black spruce in the GWR area (22 trees from sample plots 30—33, 35, 40—42). Table XIV a longer black spruce series, 1771—1946, from the same area (6 trees sample plots 30 and 31), Table XV a white spruce series from the islands off the coast (13 trees from sample plots 9, 10, 13 a, 14) 1890—1946, Table XVI a white spruce series from the maritime tree-line on the mainland 1810—1946 (13 trees from sample plots 1, 11, 12, 20, 21) and Table XVII a white spruce series from the Fort George area (8 trees from sample plots 6, 18, 19), 1810—1946.

In Diagram 5 the series in Table XII and XIII are compared with each other. Black spruce and white spruce trees react fairly similarly to the annual climatic variations in the area. In Diagram 6 the white spruce series from the islands (Table XV), the mainland coast (XVI) and the Fort George area (XVII) are compared with the white spruce series from the GWR area (XII). The series coincide well and indicate the main »depressions» in growth during the period concerned, 1890—1946. On the same Diagram MARR's »master chart» from GWR is marked (with staples). The prominent minimum years during the period (1936, 1929, 1920, 1912, 1902) appear in each series. A similar comparison is made in Diagram 7 where Table XIV (black spruce from GWR) is compared with MARR's master chart and GIDDING's series from Noatak, Alaska (1941). The correlation between the Alaska and the GWR series must be fairly vague, the distance is long and the local climate different. However, some of the prominent minimum years in the GWR series (1936, 1922, 1915, 1912, 1871, 1869) appear in both series. The author intends to return to this problem in another paper.

Table XII. The radial growth of white spruce 1890—1946 at GWR.

Year:	0	1	2	3	4	5	6	7	8	9
1890	88	81	79	89	92	100	86	81	73	66
1900	84	98	74	96	87	70	76	72	55	50
1910	53	60	41	49	44	42	55	64	55	62
1920	46	58	58	62	56	48	45	40	56	38
1930	52	46	49	48	47	54	40	52	54	49
1940	48	57	51	44	44	42	44	—	—	—

Table XIII. The radial growth of black spruce 1890—46 at GWR.

Year:	0	1	2	3	4	5	6	7	8	9
1890	54	52	49	52	48	66	60	66	59	58
1900	61	64	56	62	60	57	60	57	53	57
1910	68	69	46	59	50	42	49	54	46	50
1920	44	50	44	51	49	42	35	41	48	36
1930	40	42	39	36	38	50	38	42	45	39
1940	33	47	44	41	43	41	43	—	—	—

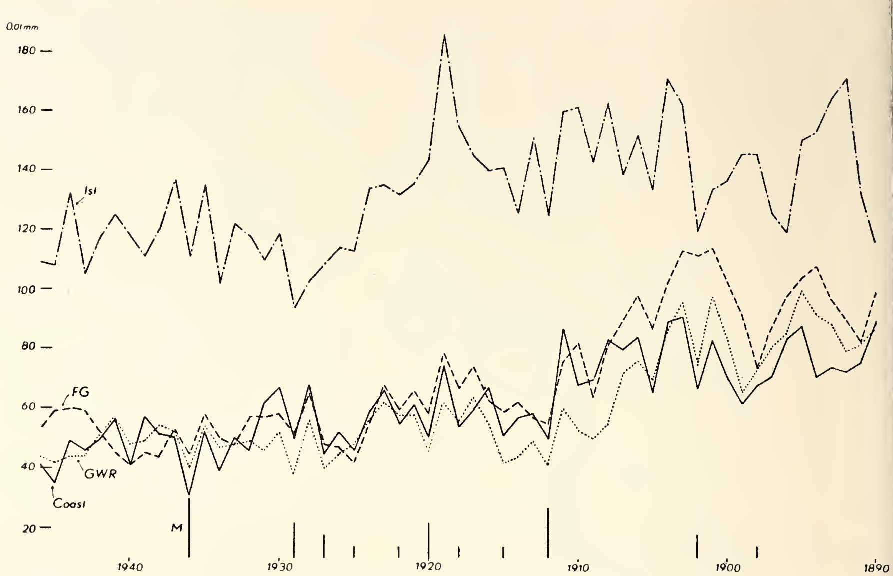


Diagram 6. Tree growth series (radial growth) from the east coast of James Bay and Hudson Bay. *Isl.*=series XV, *Coast*=series XVI, *FG*=series XVII, *GWR*= the white spruce series from Great Whale River, see Diagram 5. *M*=Marr's (1948) so-called »minimum» years.

Table XIV. The radial growth of black spruce 1771—1946 at GWR[1].

Year:	0	1	2	3	4	5	6	7	8	9
1770	—	79	69	71	38	48	65	75	65	86
1780	80	91	100	62	93	102	68	74	68	63
1790	58	54	49	44	41	58	48	57	42	59
1800	49	52	69	52	50	47	51	58	47	40
1810	40	40	44	34	31	35	32	42	40	38
1820	41	42	43	47	31	40	46	37	52	48
1830	52	43	43	44	43	29	37	33	29	35
1840	32	38	30	24	29	32	30	25	30	33
1850	37	37	33	33	32	31	30	26	30	32
1860	33	38	32	34	38	36	28	33	34	26
1870	37	30	35	41	38	27	26	28	34	30
1880	35	36	36	34	36	33	33	36	27	22
1890	26	27	23	26	24	27	26	26	23	23
1900	24	24	25	25	24	25	26	23	22	22
1910	25	30	20	22	24	20	22	26	23	24
1920	20	24	22	25	25	20	17	25	26	22
1930	23	25	26	22	25	26	20	23	21	20
1940	16	23	24	21	22	22	23	—	—	—

[1] 1771—85 2 trees, 1786—1815 3 trees, 1816—1946 6 trees.

Table XV. The radial growth of white spruce on the islands, 1890—1946.

Year:	0	1	2	3	4	5	6	7	8	9
1890	116	132	172	165	154	151	120	126	146	146
1900	137	134	120	162	171	134	152	139	163	143
1910	161	160	126	151	126	141	140	145	155	186
1920	144	136	132	135	134	113	114	108	103	94
1930	119	110	118	122	102	134	111	137	121	111
1940	118	125	117	105	132	108	109	—	—	—

Table XVI. The radial growth of white spruce on the mainland coast, 1810—1946.

Year:	0	1	2	3	4	5	6	7	8	9
1810	51	69	59	59	65	65	23	34	49	42
1820	37	59	56	46	27	13	19	21	24	24
1830	36	35	40	64	54	33	66	61	34	39
1840	42	51	52	42	38	50	77	70	79	98
1850	96	102	104	125	127	101	111	93	107	82
1860	96	109	98	88	81	88	70	105	90	75
1870	95	59	65	88	88	98	112	103	99	74
1880	94	97	90	81	80	104	90	105	80	85
1890	89	76	73	74	71	88	84	71	68	62
1900	71	83	67	91	89	66	84	80	83	70
1910	68	88	50	58	57	51	67	60	54	74
1920	50	61	55	66	59	46	52	45	68	50
1930	67	62	46	50	39	52	31	50	51	57
1940	41	56	50	46	49	35	41	—	—	—

The following years appear, i. a., as minimum years in the radial growth series from the area covered in this paper: 1774, 1783, 1794, 1798, 1805, 1814, 1824, 1835, 1838, 1843, 1847, 1857, 1866, 1869, 1871, 1876, 1889, 1908, 1912, 1920, 1922, 1926, (1929), 1936 and 1940. These years were probably marked by a low summer temperature. The cambial activity awakens late at the maritime tree-line in this climatically exposed areas — in 1947 it was not until the first days in July. It must also be stressed that poor radial growth in a certain year does not always mean climatically unsatisfactory years. An unusual rich cone formation can cause a »slowdown» in cambial activity. The true correlation between growth and climate and between cambial activity and flowering intensity is not easy to establish (H 1948). Lack of climatic series from the area does not permit the author to make any correlation calculations. Almost certainly a strong correlation exists in this area between

Table XVII. The radial growth of white spruce near Fort George, 1810—1946.

Year:	0	1	2	3	4	5	6	7	8	9
1810	169	171	138	117	120	124	80	84	105	97
1820	106	104	126	105	86	94	109	67	78	89
1830	100	82	82	94	114	69	72	99	112	112
1840	91	81	80	65	86	82	91	84	53	65
1850	70	73	86	82	96	77	99	97	86	82
1860	77	79	77	65	73	63	72	89	103	104
1870	113	101	114	104	103	95	102	110	114	111
1880	125	134	130	110	106	91	86	80	72	108
1890	100	83	90	97	108	104	98	87	74	91
1900	103	113	112	113	102	87	98	90	81	64
1910	82	76	55	57	62	59	63	74	67	78
1920	59	66	60	68	55	42	47	48	65	52
1930	58	57	57	48	50	58	45	53	44	45
1940	41	45	52	59	60	59	53	—	—	—

the radial growth and the temperature in July—August. Otherwise, this forest near the polar forest limit would represent an exception from the general rule, compare ERLANDSSON 1936, GIDDINGS 1941, 1947 and H 1948.

The Tables X and XI show further that the growth in thickness is fairly uniform on different forest types. This feature has, according to the author's opinion not been sufficiently stressed by the dendrochronologists. One would

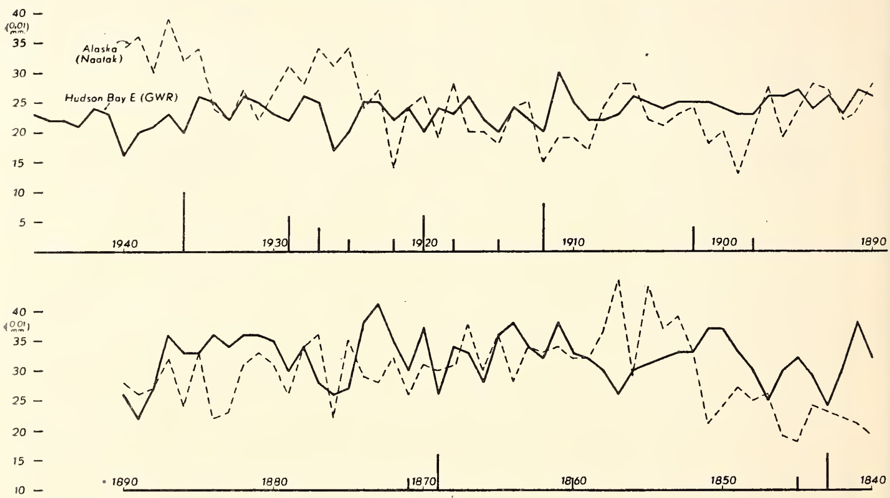


Diagram 7. Giddings (1941) Alaska series (Noatak, white spruce?), compared with Marr's (1948) series (the vertical lines) from GWR and the author's GWR series (Table XIV).

expect greater differences between coast and inland forest types and between dry and moist forest types. The material is satisfactory for the last decades only. When we penetrate into earlier decades with a such dendrochronological material, the error coefficient increases, especially in a small material. Also, there are generally less components in the earlier years in the series, compare the note to Table XI.

*

(A summary is excluded, because the general observations which appear here are already included in my paper on the forest geography of the Labrador Peninsula, 1949.)

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[1] See also Extracts from Reports on the District of Ungava, Third Ed. Quebec 1929.

ACTA GEOGRAPHICA 11, N:o 2

ON THE GEOLOGY OF THE EAST COAST OF HUDSON BAY AND JAMES BAY

OBSERVATIONS DURING A RESEARCH JOURNEY IN SUMMER 1947

BY

E. H. KRANCK

HELSINKI 1951

Contents.

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Introduction.

This paper is based mainly on observations made during a research journey in the summer of 1947. The field work was financed by the United States Naval Research through a fellowship awarded by the Artic Institute of North America. I wish to express my gratitude to both these institutions for their assistance in making this expedition possible.

The chief object of the voyage was to study the petrology of the archaean rock-ground but at the same time I had the opportunity to observe the geomorphology and was able to draw some general conclusions. It is only a brief report which does not attempt to give any definite solutions of the problems outlined; its object is only to pose a few questions which may be of some interest for more detailed future researches.

Owing to shortness of time only a few additional data were obtained concerning the topography of the coast, and the description corresponds mainly to those of Low, Bell, Manning and other earlier explorers.

Acknowledgements.

The journey, in which I was accompanied by the botanists, Dr I. Hustich and Dr. R. Tuomikoski from Helsingfors, Finland, Mr. W. Baldwin from the National Museum in Ottawa and Mr. J. Kucyniak from the Botanical Garden of Montreal, was organized in cooperation with the National Museum, who supported our work in many ways. I particularly want to thank Dr. Porsild, the chief botanist of the National Museum, who took great interest in our expedition.

Further I want to express my most cordial thanks to all my companions on the journey and particularly to Mr. Baldwin, who managed the practical preparations of the expedition perfectly. To the employees on the H. B. C. stations visited by us, above all Mr. Duncan at Moosonee, Mr. Webster at Great Whale River and Mr. Trafford at Port Harrison who, following the traditions of the Company, facilitated our research work in every way, I want

to express my sincere thanks. I also want to thank Canon J. C. Sheppherd of Fort George who kindly gave me permission to use the mission station at Port Harrison during my stay there.

Earlier research work.

The most important source of information concerning the geology and physiography of the eastern shore of Hudson Bay is still the excellent report of A. P. Low on his exploration in the years 1898 and 1899 and the reports of Bell of 1877 and 1878.

Later geological work has chiefly dealt with the economic aspect. A detailed description of the Nastapoka Islands with special reference to the iron ore deposits was given by Low in 1912. Leith also has given a short report concerning the iron-bearing sediments.

Our knowledge of the eastern parts of Hudson Bay has since then had the important addition of the rediscovery of the Belcher Islands by Flaherty in 1916. His was the first scientific description of this peculiar archipelago. In 1929 Moore carried out a geological investigation of the major islands and published a brief geological description including the only existing geological profiles of the Belcher series. Other prospecting parties have also visited the coast but without publishing any scientific reports. On the other hand quite a number of descriptions of journeys in the coastal regions bordering eastern Hudson Bay give certain general information concerning the physiography, but very little of geological interest.

The most recent publication dealing with these regions is an interesting account in the Geographical Journal by T. H. Manning, the most prominent expert on the topography of the eastern Arctic of Canada, of his exploration work in 1940. This paper also gives a complete account of explorations along the east coast of Hudson Bay during earlier times.

General character of the area.

The east shore of Hudson Bay is, in spite of the comparatively low latitude, one of the most desolate regions of Canada. Except round the southernmost parts of James Bay, the severe climate renders all agricultural activity impossible.

Hunting is comparatively poor and Hudson Bay lacks sufficient fish to make large scale fishing profitable. Prospecting for minerals has also so far had little success. For these reasons the population along the coast is still

very small, and living between Cape Wolstenholme and Rupert House there are only about 15 white families and about 1,000 natives.

Communications are therefore very little developed and in general it is impossible to rely on local means of transport. On the southern parts of the coast there are very few boats and only as far north as the Port Harrison region have the natives such craft as can be used for exploring. The supply ship of the Hudson Bay Company makes a few trips every summer from Moose Factory to the southerly posts up to Great Whale River. From Port Harrison northwards the posts get their supplies direct from Montreal along the northern route, once a year. During the summer months there is an air service from Moose Factory to Port Harrison about every month and a few times during the winter.

Navigation without native pilot is difficult along the James Bay coast owing to the shallowness and the numerous shoals. In contrast the coastal section between Cape Jones and Portland Promontory does not offer any difficulty and can easily be navigated even without a pilot both with small boats and bigger craft. North of Portland Promontory the same difficulties are met with as in the James Bay area. In the northern regions particularly the weather conditions are rather unfavourable, with much fog and wind, and often with drift ice until middle of August.

Geomorphology.

The coastal section Rupert House — Cape Jones.

The east shore of James Bay is a plain of archean granites and gneisses, with a gentle inclination towards the sea. Along the contact between sea and land the slight roughness of the topography has given rise to an extremely indented coast line with numerous small islands and shoals. The difference in altitude between the highest and lowest points in this peneplane-surface nowhere exceeds 150 feet. Plains in the strict sense of the word, on the other hand are rare and of small extent, owing to the thin covering of drift and alluvial deposits. The higher portions of the rockground are everywhere bare and post-glacial deposits are found only in depressions and valleys. As will be shown later there is a gradual change in the topography of the coastal region from south to north.

The southernmost part, at the estuary of Rupert River and Nottaway River, along the contact of the Devonian sediments of the southern parts

of the James Bay area and the pre-Cambrian shield, is still comparatively hilly with Sherricks Mount (700 feet) as the dominating landmark north of the entrance to the river mouth. There seems, however, to be a row of hills farther inland, following the sedimentary boundary. The small islands off the coast are often rather steep and rocky, the most conspicuous being Stag Island in the middle of the entrance. Tectonic movements (faulting) have evidently taken place along the line where the pre-Cambrian shield meets the unmetamorphosed paleozoic sediments.

The water is everywhere extremely shallow and there are wide sand bars and also several low sandy islands rendering the approach to the coast difficult even in small boats.

Farther north the islands are generally low and formed of drift and boulders accumulated around ice-sculptured rocks of granite and gneiss. The coast is open for long distances as far north as the Cape Hope Islands (28)[1], the only good harbour is at mouth of East Main River.

The Cape Hope Islands have a higher topography with bold, rounded hills 300—400 feet in height and visible from a long distance. They evidently represent monadnocks left on account of the resistance of the metamorphic greenstones composing the rockground.

The skyline inland from the coast is that of low hils, the main contour is more or less horizontal.

North of Cape Hope, around Old Factory, is a stretch of coast line with many small, mostly low, islands, rising only 20—50 feet above sea-level. They generally consist of granitic rocks but sometimes of sandy moraine ridges e.g. the islands on which the Hudson Bay Company post of Old Factory is situated. This region very much resembles the »skargard» (skerries) of the north coast of the Gulf of Finland. The inner islands are covered with forest vegetation, the outer islands are barren.

The »skargard» of Old Factory is separated from the next long point of land with its islands, the Paint Hills (27), by a broad open bay. The Paint Hill Islands are again comparatively high and consist of metamorphic greenstone and syenite, the former possibly connected with that of Cape Hope Islands. They are about 150 feet or a little more in height. The mainland opposite the islands is also rather hilly.

From Paint Hill northward the topography is very low and the smooth sounded granite rocks of the islands rarely reach more than 40—50 feet above sea-level. Glacial drift begins to play a more prominent role in the topography, for-

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[1] The numbers refer to the scetch map. Fig. 36.

ming elongated drumlin-ridges mainly running east-west. They often form long points of land and sandy islands outside the fringe of rocks and shoals of the coast.

Figure 1. The portage of Cape Jones with low gneiss hills in the background.

The coastal section south of Fort George River has a very complicated »skargard» with narrow channels between low granite islands. North of the estuary are three broad bays, of which the largest and most northerly is Paul Bay. (The aeronautical chart has given the name Paul Bay to the one south of that of Low and of the 35 mile to 1 inch map.) The coast is rather open and islands lie mainly around the points.

From about Beaver River (21) northward there is a noticeable change in the topography and the low coast becomes still lower (cf. fig. 1). The skyline is almost horizontal and the elevations do not exceed 20 feet. The average difference in height is only a few feet. The most prominent points are generally those of drumlins. Yet in spite of the lack of hills outcrops of archean rocks are by no means rare all along the shores. Inland the rockground is mostly covered by a thin layer of glacial drift and sand forming a coastal plain several miles broad. This type of topography prevails with increasing flatness until Cape Jones (19).

Cape Jones, the »boundary» between James Bay and Hudson Bay is a rocky cape consisting of a row of rounded hills 120—150 feet in height. Owing to the lowness of the surrounding landscape they appear much higher when seen from the south, and are visible from a distance of 20—30 miles. Cape Jones is also the boundary between two coastal types of entirely different morphological character and its hills occupy a similar position in relation to the late-pre-Cambrian sediments of Hudson Bay as Sherricks Mount in relation to the Devonian sediments of James Bay.

The coastal section Cape Jones — Portland Promontory.

Between Cape Jones and Portland Promontory the coast is remarkably smooth, forming a great semicircle of which certain stretches are sheltered by a single row of islands, but without a »skargard» of the type we find at James Bay.

From Cape Jones eastward for about 50 miles the coast still is low. The hills extend eastward for at least 20 miles but they are several miles inland and therefore are not a conspicuous feature of the coastal topography. The most interesting feature of the coast is the fringe of islands beginning with the big Long Island formed of unmetamorphosed sediments with sills and basaltic beds. Their topography is everywhere the same; steep cliffs facing the land and gently dipping slopes towards the sea. This topography is due to the position of the sedimentary layers which dip 5—10° seaward. The sediments have been referred to the uppermost pre-Cambrian.

The cliffs of the south shore of Long Island rise to a height of about 200 feet above sea-level, the small islands between Long Island and the mainland are all low.

About 50 miles east of Cape Jones at Little Cape Jones (17) the coast suddenly becomes higher, with granite hills rising direct from the shore to over 300 feet. Beyond the rather steep coastal slope there seems to be a plateau of considerable extent with an almost horizontal skyline. Evidently the coast is here cut by a faultline.

From this point eastward for more than 100 miles the coast is open and deep, with only a few scattered islands close to the mainland which is still rather high, about 200 feet, but has generally a sandy strip of low land, a couple of miles wide, between the shore and the hills. This lowland is in some places — for instance at the mouth of Sucre Creek (16) — so broad that the hills are almost invisible from the shore. The rockground of this low stretch of land consists partly of proterozoic sediments (cf. Low's geological map).

The contact between the archean rocks and the overlying sediments has in earlier descriptions been explained as an overthrust, or in any case as a zone of strong displacements. I had an opportunity to study the contact about 2 miles from Otaska Harbour, 24 miles west of Great Whale River (14) (cf. also p. 81). The sediments of gray limestone in lower strata have exactly the same seaward position as those of the islands and rest directly on the granite without any trace of tectonic disturbances (cf. p. 80). There are no traces of folding in the sediments except at some places (e g. Black Whale Harbour) where the layers have been disturbed by faults.

From Black Whale Harbour (15) to the mouth of Great Whale River the granite hills rise directly from the sea whereas the few islands outside consist of sediments. The slope of the shore cliffs is rather gentle, and corresponds to the tilted position of the sediments outside (cf. fig. 2).

The surface of the granitic shore cliffs is the old regenerated base of the proterozoic formations as is proved by the numerous small joints in the granite filled with yellowish dolomite or chert, in many cases also pyrite and marcasite: all these minerals are found in the younger formations. These joints and veinlets which often appear as a slight brecciation are found already at Cape Jones.

About 8 miles northeast of the estuary of Great Whale River, on Bill of Portland Island there is on the shore of the mainland a very definite contact between the sediments and the underlying granite. The undermost layers of the former is a boulder conglomerate intermixed with mudstone layers having distinct sun-cracks and ripples. The granite shows traces of an old lateral weathering. There are no indications of tectonic disturbances.

Northeast of Great Whale River there is, outside the Manitounuk Sound, a continuous row of islands consisting of sediments under the basalt beds which form the upper surface. Except for a very slight undulation there is no folding in the sediments.

From the northeastern part of

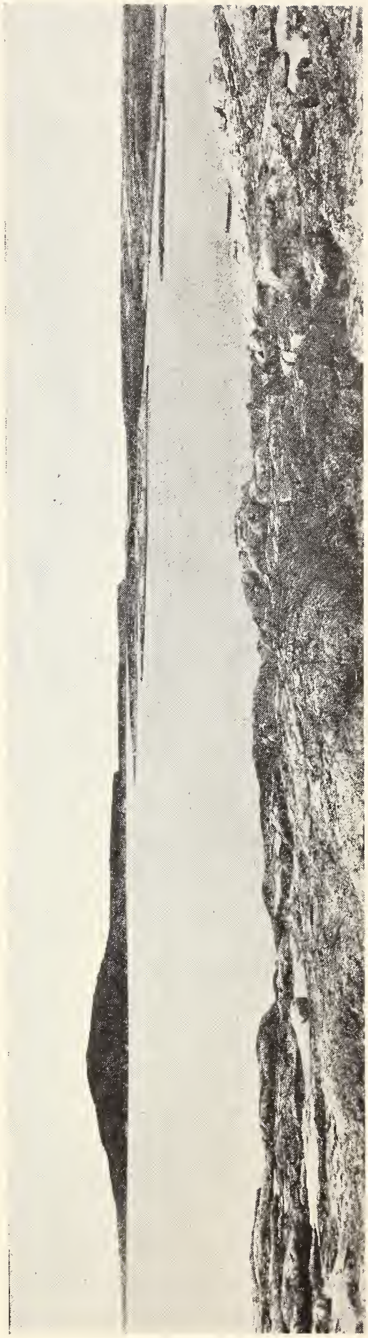


Figure 2. The granitic sub-proterozoic landsurface with remnants of proterozoic sediments. N of Great Whale River.

Manitounuk Sound the sediments extend over considerable areas on the mainland, forming bold cuestas covered withbasalt. The topography rises higher than at any other part of the coast. The row of islands in Manitounuk Sound continues on the mainland as cuestas, and an outer fringe of islands called the Nastapoka Islands extends for about 100 miles northward. The low Duck Island also belongs to the same fringe.

The inland topography between Cape Jones and Great Whale River is very imperfectly known. So far as could be seen when travelling in bad weather by plane from that river to Fort George there is a small hilly upland plateau with innumerable lakes extending from the region east of the river to the coast at James Bay. I have not been able to confirm whether the coastal mountains are a higher range running parallel with the coast-line, but it seems so. South of Burton Lake the peneplane surface is traversed by a number of comparatively deep tectonically formed furrows giving rise to a number of long and narrow lakes.

The region of Great Whale River is hilly, with elevations from 300—400 feet (Fig. 3). The landscape is crossed by several valleys at right angles to the coast, probably formed by preglacial erosion. Between Great Whale River and Little Whale River the hills are higher along the coast than farther inland, which explains the northeastward bend of the former.

The Richmond Gulf (11) area is

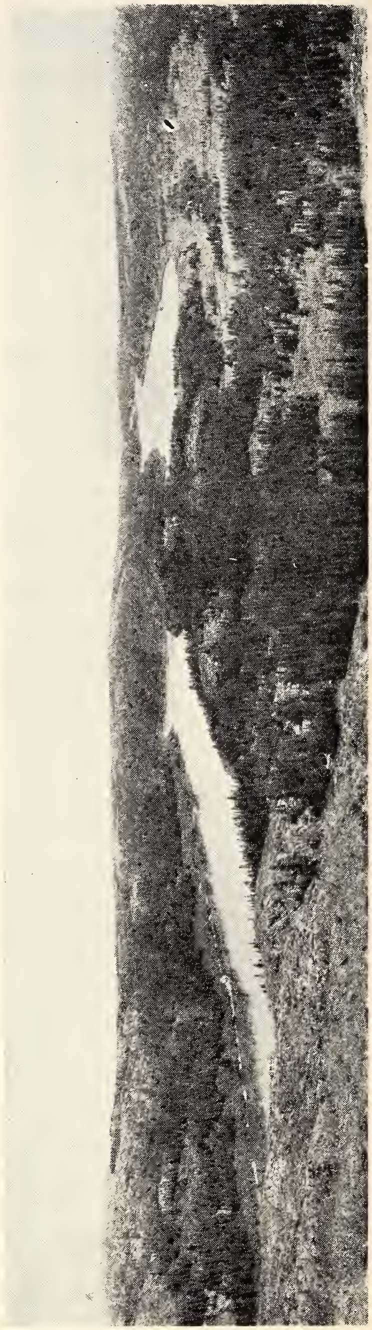


Figure 3. The hilly inland-topography of the coastal region at Great Whale River.

probably from a geomorphological point of view, the most interesting part of the coastal section and the topography here shows clear indications of strong tectonical movements. The sediments and diabase beds are tilted in different directions, and the faulting has evidently taken place over a considerable area. I was not able to detect any definite proof of folding when crossing the region by plane, but a ground survey may reveal traces of a comparatively slight folding with a north-south axis.

Figure 4. Glacial topography of the Coastal Range between Langland River and Nastapoka River.

Richmond Gulf itself evidently represents a fault »Graben» limited by fault lines, but, as will be shown later, with a definite realtion to the folding of the Belcher Island sediments. Particularly north of the gulf is a very clear structural boundary between the uplifted blocks on the north side and the low terrain around the bay. Around Richmond Gulf the mountains rise over 1,500 feet above the sea level. Here the proterozoic formations extend farther inland than at any other part of the coast, and also east of the gulf. North of Richmond Gulf sediments are lacking on the mainland and the diabase layers rest directly on the granitic base.

The Nastapoka Islands described in some detail by Low consist mainly of sediments which generally also form the crests of the mountains, and abound with iron-bearing layers. On the mainland the rockground evidently consists of the same diabase as at Manitounuk Sound at least 30 miles north from the Gulf. The basal beds are frequently traversed by erosion valleys, of which many are dry and evidently arose during pre-glacial times, some of them possibly already before the last tectonic movements in this area.

North of Richmond Gulf the coast is very smooth for about 100 miles and the shores consist of granite cliffs. The southerly section is still rather high and hilly, the crests of the heights reaching 800—1,000 feet. In the crests there seem to be remnants of an older land surface which has been cut by a later erosion. The glacial erosion has been everywhere extremely strong and has

Figure 5. Topography of the Coastal Range north of Nastapoka River with fault line in right angle to the coast line.

given rise to small cavities in the rockground now forming lakes (Fig. 4). Several big fault lines at right angles to the coast line are visible.

This mountainous terrain does, however, not extend very far inland. From the plane it was clear that the land for about 30 to 40 miles from the coast is very flat and covered with innumerable lakes of all sizes forming a »lake plateau» of the type known from other parts of the pre-Cambrian shield of Canada and from central Finland.

Thus there is a well-defined coastal range which can be followed northward up to Portland Promontory. This physiographical feature has also been pointed out by Manning in the paper already mentioned which also has some photographs illustrating the topography of this part of the eastern shore of Hudson Bay.

The coastal range becomes lower and narrower towards the north. Clear fault lines are found at Langland River and parallel with another river about 10 miles farther north, which is not shown on the maps. It can be seen in the photograph Fig. 5. At Langland River the Coastal Range is not more than about 15 miles broad.

The island fringe is absent for a distance of about 40 miles up to Hopewell Point about 58°20′ North.

From Kikertuluk River northward the coast is again more indented. The river ends in a long fjord-like bay (cf. the air-photograph published in Mannings paper). Another bay of about the same size called Hotchkiss Inlet is schematically marked on the coastal maps. Its shape is shown by the photograph, Fig. 6. A number of smaller bays offer good harbours and anchorage for small craft.

From Hopewell Point to Portland Promontory the coast resembles the Manitounuk Sound region, with a fringe of islands consisting of the same

Figure 6. Hutchkiss Inlet at the eastern end of Hopewell Sound.

unaltered sediments and diabases. The proterozoic rocks are here found only on the islands, the coast of the mainland consisting of archean rocks forming low cliffs partly covered with drift and sand. The coast terrain is low for about one or two miles inland, after which the hills rise rather abruptly to 300 or 400 feet above sea level.

The coastal range is only some miles broad but clearly visible. In the region of Port Harrison the ridge practically consists of only one row of hills sloping gently towards the sea, but with rather steep bluffs on the inland side, as is the case with the islands outside. The angle of the seaward slope corresponds also here approximately with that of the sediments.

I was able to study the contact between the sediments and the archean on the north side of McCormack Islands, and here too the sediments rest in their original undisturbed position on the gneissic base.

The coast west or northwest of Port Harrison is very indented and has an extensive »skargard» inside the sedimentary island fringe, sculptured in the archean peneplane.

The coastal range is visible from the inner parts of Which Bay (Kanakoraroluk) (16), with heights rising to about 500 feet above sea-level. The hill on the west side of Port Harrison is, according to barometric determination, 420 feet high. There is a marked relation between the topography and the composition of the rockground. Basic rocks mostly remain as higher hills, evidently because they have better resisted the erosion, and above all the ice erosion than do the granites and gneisses. The hills composed of basic rocks also often show more ragged outlines than those composed of granites.

The western coast of Portland Promontory is generally low but still hilly. The small rocky islands outside are completely levelled and smoothed by glaciation and the crests lie only 10—20 feet above sea-level. The inland topography of the northern part of the promontory is also very flat having heights of only a few feet.

The coastal section Port Harrison — Cape Wolstenholme.

The northernmost part of the east coast of Hudson Bay will here be only briefly described as it lies outside the regions known to the author.

North of Portland Promontory the coast is low and shallow and is in many respects like James Bay. The inland is partly covered with drift forming a swampy terrain between low ronded granitic hills. This type of coast extends to Cape Smith where a row of comparatively high hills run from east to west down to the coast. They consist of basic igneous rocks, partly metamorphosed into greenstone schists. Their position is not yet clear.

The hills are between 500—1,000 feet high.

North of Cape Smith the coast is again low and fairly indented until the region of Navak where the high rocky topography of the south coast of Hudson Strait begins. The hills at Nouvak are about 500 feet high but rise considerably in a northerly direction. At Cape Wolstenholme the crests rise to a thousand feet and more.

Thus the topography of the region of Cape Wolstenholme corresponds, as regards elevation to that of the region of Richmond Gulf.

Some geomorphological problems of the coast.

The subdivision of the east coast of Hudson Bay employed in the foregoing description is the same as was adopted by Low. The physiographical character of the three main sections differ considerably and present a number of geomorphological problems.

The east coast of James Bay.

Compared with most parts of the world this coast is a picture of the utmost monotony. For hundreds of miles the topography shows hardly any important changes and the low ice-sculptured cliffs along the shores and the rounded hills inland are only exceptionally visible for more than a few miles off the coast.

Thus the general topography offers few, if any, problems which can be studied within a limited section of the area. It is worth mentioning that the composition of the rockground is also monotonous. With very small variations the same type of archean granites and gneisses are found all along the coast, with only scattered and less extensive rocks of varying composition. Actually, a more varying rockground will not be found until as far north as Port Harrison.

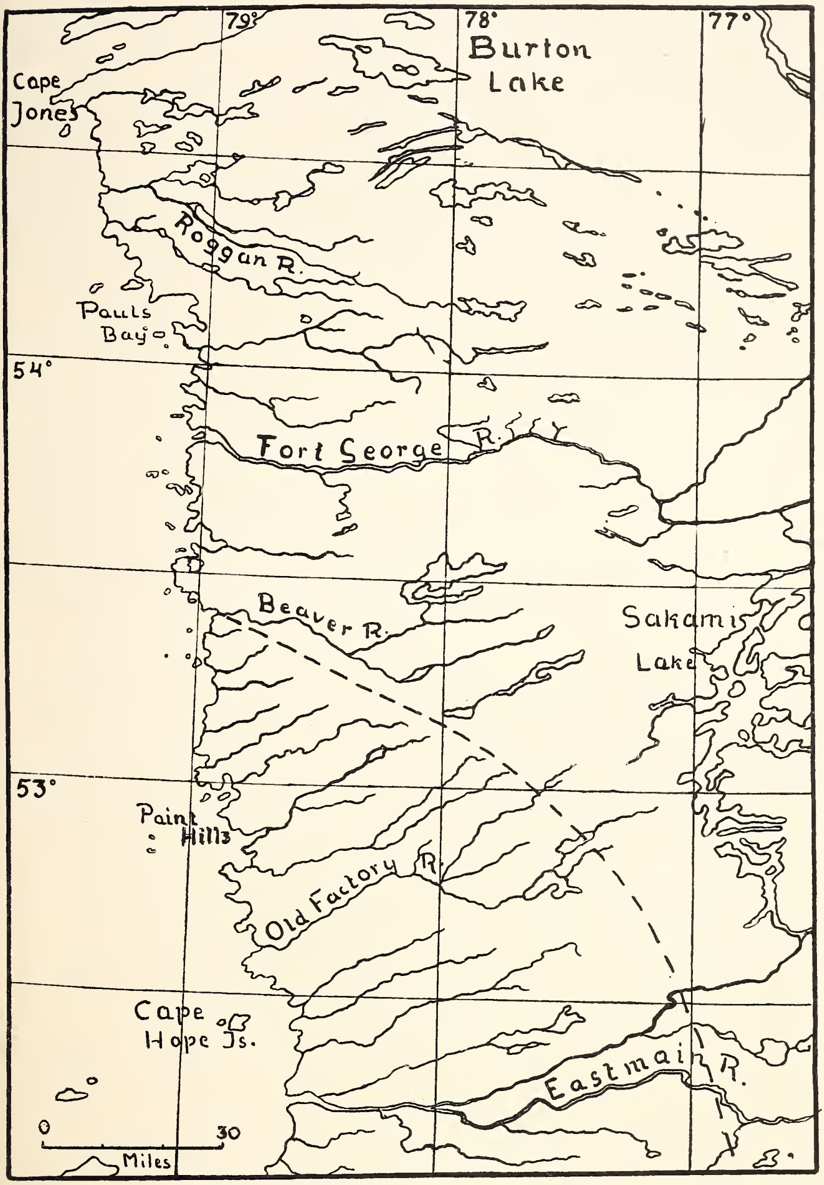


Figure 7. Sketch map showing the hydrography of the mainland east of James bay.

This extreme monotony is however itself one of the most fascinating features of the country. It proves that here is a part of the earth's surface which has remained tectonically static for aeons of time during which geological agencies have brought the topography to a stage of maturity approaching an ideal peneplane as near as possible. If there is any part of the world where the slogan »our mobile earth» can be replaced by the expression »our stable earth», it is the James Bay region. This of course does not mean that no traces of movement in the earthcrust whatever, are to be found, but only that these traces derive from the oldest archean time or else depend on very recent slow movements of an epeirogenetic type.

The most conspicuous feature is the peneplane sculptured in the old pre-Cambrian shield.

Kindle refers the whole east coast of James Bay so far north as Cape Jones to the *coastal plane of James Bay* and corsequently to the same land surface as the areas of paleaozoic sediments. From a purely topographical point of view this statement is entirely defensible and perhaps also from a genetical point of view. There are, however, facts which show that the question may be more complicated though no attempt is here made to find a definite solution of the problem.

In the description of the past a slight difference was mentioned in the coastal type south and north of about Beaver River the former being lower and more level than the latter. If we study the latest aeronautical chart of the region (AAF., 180, 1945) some features will be found in the inland hydrography which evidently have a certain connection with this difference.

A glance at the map (Fig. 7) shows that the hydrographic pattern of the mainland drained to the coast south of Beaver River, has a very different aspect compared with that farther north and east. The former is characterized by a number of small rivers running all in the same direction at right angles to the coastline. Lakes are rare, except in the vicinity of the watershed. The latter has a very irregular topography with innumerable lakes of all sizes which drain in varying directions. Here is a typical almost horizontal lake-plateau, with a very gentle slope to the north-west. Between these regions there is a secondary watershed, which however in fairly diffuse and traversed by the major streams, like East Main River, Fort George River, etc. This secondary watershed runs from about the mouth of Beaver River in a south-easterly direction.

It is evident that the inland peneplane north of this watershed dips at an extremely sharp angle down to the coast and dives under the sea, forming the low archipelago of the northern coastal section. I believe, without having

any definite proof that this peneplane surface corresponds with the peneplane of the paleozoic areas south and west of James Bay.

As to the land surface west of the secondary watershed, we must take into account the possibility that here is a fragment of an older peneplane. The topography seems to be slightly more uneven and the absence of lakes indicates a slightly greater inclination towards the sea. I have, however, seen too little of the land to state whether these conditions are due to a comparatively more even surface of drift and alluvial deposits.

Another possibility is, of course that the secondary watershed may depend on tectonic conditions, for instance faulting. Crossing the watershed by plane I could not detect signs of tectonic displacements in this region.

The southerly section of the coastal plane of the east coast of James Bay, may possibly represent the old surface on which the paleozoic sediments were deposited. The peneplane of the interior would then be of post-Devonian, possibly Cretaceous, age and would cut the sub-Cambrian peneplane at a slight angle. A similar explanation of the relation between the coastal plains of the Gulf of Bothnia and the peneplane of the Lake-Plateau in central Finland is given by Tanner. This question requires, of course, a much deeper study of the topography, in order to allow a definite answer.

A study of the disposition of lakes and rivers farther inland reveals a peculiar parallel arrangement on a great scale which more or less follows the direction of the secondary watershed mentioned above. East of it there is a stretch of land, about 50—60 miles wide, comparatively poor in lakes, evidently representing a low ridge. Still farther east there seems to be a slight depression running in the same north-west south-easterly direction, in which lies the great lake Sakami. There we again have an area with few lakes. Then follows the region rich in deep, elongated, tectonic lakes, mentioned in the description of the Great Whale River region. From the map one has the impression of a very gentle undulation of the peneplane surface parallel with an axis running mainly north-west-south-east. The extent of this undulation is, however, so enormous compared with the height that it is invisible to the human eye from a distance. For this reason it has no influence, or only a very slight one, on the course of the major streams.

Another geomorphological problem of the James Bay shore is the formation of the »skargard» to which a few words will be devoted here.

The east coast of James Bay and certain parts of the northern section of the Hudson Bay coast offer a good opportunity to study the morphology of the »skargard» which in recent years has been the subject of a certain interest in North European countries. Hudson Bay, and James Bay, certain parts of

the north shore of Bay of St Lawrence, N coast of Labrador and possibly some other coastal sections of Arctic Canada are, so far as I know, the only parts of the world where the geomorphology of the »skargard» corresponds exactly to that of the »skargard» of South Finland. In both regions we have a peneplane with a slightly uneven surface sloping at a small incline under the sealevel. The islands close to the coast are generally larger than those farther out to sea. The distribution and form of the islands depend partly on the tectonic transformation of the peneplane by jointing and faulting partly on the old archean structure of the rock ground itself. The influence of the old structure is visible, where there is a marked schistosity in the rock ground or where very resistant (basic) rocks stand out in relief.

The role played by the quaternary deposits is very different in different sections of the coast and will be specially described. The role played by the accumulation of alluvial silt resembles that of the south coast of Finland. Most big bays have been filled up and therefore form very shallow flats often of considerable size. At low tide they are almost dry and inaccessible even by small boats. Goose Bay, Paul Bay and other inlets offer good examples of this phenomenon.

The coast of the Belcher Basin.

The morphological problems of the long coastal section between Cape Jones and Portland Promontory differ in most respects from those of the James Bay shore.

The coast forms a great semicircle and the coastline is generally very smooth, without indentations. A conspicuous feature is the row of large islands of sediments resting unconformably on the old archean rockground, evidently representing the edge of a sheet of sediments covering the bottom of the basin.

Another feature of importance is the coastal range described above. It is, however, less pronounced along the south part of the coastal section than on the north. There seems to be no doubt that this range is due to a fault-line running parallel with the coastal arch some miles inland. It has evidently been formed in connection with a tilting of the sediments (cf. fig. 8).

There may be several similar fault lines farther out in Hudson Bay, giving rise to the outer island fringes.

In the innermost (easternmost) part of the coastal section around Richmond Gulf, the coastal range is very broad and has a more complicated structure, owing to several fault zones which have tilted up certain parts of the range

as separated blocks, while others, especially the Richmond Gulf, represent a tectonic Graben.

The most interesting detail in the east of Hudson Bay is, however, the Belcher Islands which have been mapped in detail from the air and can therefore to a certain degree be interpreted tectonically in spite of our imperfect information about its geology.

The archipelago evidently represents a peneplanized folding zone resembling certain sections of the Jura Mountains, particularly the French Jura, with a combination of folding and faults. The present relationship between the topography and the structure evidently depends chiefly on the different resistance force of the different layers, the harder layers being sculptured in relief whilst the softer ones form the lower parts of the topography. There is in general an inversion of the topography and the anticlines are mostly covered by water and form the straits. The position of the peneplane surface in relation to the sea-level allows the present coast-line to give a clear picture of the structure.

The Belcher Islands seem to be situated in an axial depression, the folding axis in the northernmost part of the major islands dipping southward in the southern parts northwards. It is interesting to note that on the mainland opposite this axial depression we find the tectonically disturbed region of Richmond Gulf. The fault Graben of this area evidently corresponds to the latter.

A swift glance on the map at once shows that there must be a close relationship between the Belcher folding and the general shape of the coast of the Belcher Basin. The bow shape of the islands corresponds to the semicircle of the mainland coast, which consequently is also true of the fault line between the range and the inland plain. All these structures run more or less parallel with the folding axis of the islands.

It is quite possible that the Belcher Basin and consequently also the present shape of its shore was formed in connection with the folding of the proterozoic sediments. The direction of the fault forming the coastal range parallel with the curves of the islands and the axial direction of the folding strongly support such a supposition. On the other hand it would hardly be correct to interpret the present relief as surface forms remaining from pre-Cambrian times.

As was already stated the present peneplane relief of the Belcher Islands evidently originated during the same cycle of erosion as formed the peneplane (or peneplanes) of the mainland. This peneplanization of the Belcher zone undoubtedly took place after the Devonian sediments of James Bay were deposited.

As we have seen the mainland peneplane was to a considerable degree

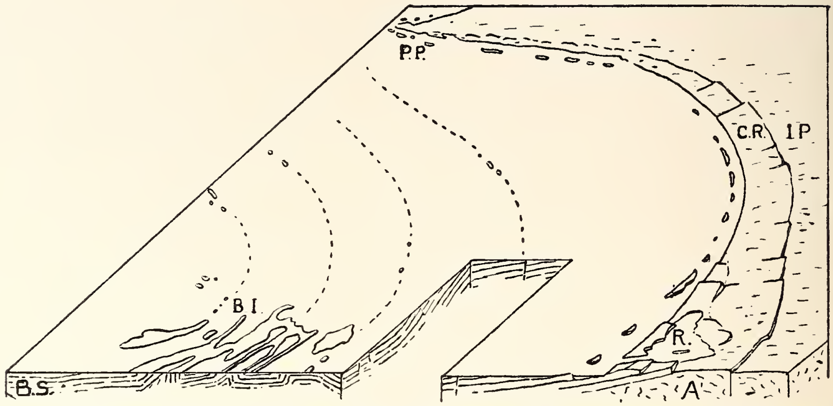


Figure 8. Stereographic scheme of the tectonic main features of the eastern parts of Hudson Bay. P. P. Portland Promontory; C. R. Coastal Range; I. P. Inland Plane; R. Richmond Gulf; B. I. Belcher Island; B. S. Belcher series; A. Archaean.

deformed by later movements, and in the Richmond Gulf area the hills rise several hundred feet above the inland peneplane on the east side of the coastal range. Farther we have seen that the Belcher Islands which to day represent an uplifted part of the basin tectonically represent an axial depression. All these facts prove that considerable vertical movements took place also after the original folding of the sediments.

The most probable explanation is that several phases of movements have taken place along the zones of weakness originally formed during the late pre-Cambrian diastrophism. It seems to me that the age of the latest fault movements in the coastal range most probably are tertiary — to date them exactly is, of course, still impossible.

The stereographic sketch (Fig. 8) illustrates these opinions. The structure of Belcher Islands is drawn according to the tectonical profile of Moore and the American aeronautical chart.

The geomorphological problems of the coast from Portland Promontory to Cape Wolstenholme.

The region north of Portland Promontory presents more or less the same problems as the east shore of James Bay. The question concerning the age and the origin of the inland peneplane, and the possible existence of several peneplane facets of different ages can not yet be discussed on account of the very incomplete field observations.

The greenstone areas of Cape Smith with their comparatively high relief are evidently due to tectonic movements of the same type as in the coast regions of the Belcher Basin. Fault lines seem to cut the coast-line in the direction southwest — northeast. Here we have to reckon with the possibility that the faults may be connected with the Belcher Islands' folding. They run in the same direction and are continued in the Ottawa Islands which consist of traps undoubtedly belonging to the same sequence of intrusions as the diabase of the Nastapoka Islands and the Belcher Islands. According to Manning they are rich in pillow lavas which he thinks may be identical with those described by Low from Cape Smith. I am not, however, sure whether this parallelism is correct. According to Low and Gunning the greenstones of Cape Smith are highly schistose and evidently resemble those of Paint Hill Islands and other archean greenstones of the coast. — (Low refers all these »traps» to the same series as the proterozoic greenstones, which certainly is not correct. l.c. 70 D.)

On the other hand from a tectonic point of view it is quite possible that the zone of tectonic movements and displacements caused by the folding turns eastward from Ottawa Islands and cuts the present coast-line at Cape Smith. If so we can expect to find several interesting problems both concerning the tectonics and the physiography of this coast section, which, however, can not be treated until we have more information about the region north of the Portland Promontory.

The hilly topography of the region of Wolstenholme and the south coast of Hudson Strait seems to have been formed by comparatively late movements, possibly of the same age as those movements which caused the high topography of Baffin Island. So far as can be understood from the available descriptions there seems to be a »coastal range» along the south coast of the Baffin Strait of about the same type as that of the Belcher Basin.

Conclusions.

Our present knowledge of the morphological history of the east shore of Hudson Bay can be summarized under the following headings:

1. Formation of the sub-Proterozoic peneplane. This evidently coincided with a long phase of regression. Small remnants of the peneplane are found along the coastal section Cape Jones — Portland Promontory.

2. Deposition of the Belcher Islands and Nastapoka series. Transgression probably interrupted by one or several stages of regression.

3. Phase of diastrophism with folding of the late pre-Cambrian sediments

(Pénakoée). Intrusions and extrusions of basic lavas, in connection with faulting.

At the end of this phase there was evidently a transgression of the sea.

4. Long phase of erosion and regression. Formation of the sub-Cambrian peneplane. This plane possibly reappears in the coastal plain on the east coast of James Bay. During this phase the Belcher Basin was at a deeper level than the James Bay area where only the dykes of the late pre-Cambrian diabase sheets remain.

5. Deposits of the Palaeozoic sediments south of Hudson Bay.

6. Stage of regression and erosion and formation of the mainland peneplane of the »lake-plateau». Possibly during cretaceous time, or still later.

7. Later movements, mainly late tertiary, which have given rise to the present mountainous topography of the east coast of the Belcher Basin.

8. Glacial and postglacial movements and transformation of the earth crust.

This list of geological events is of course not complete. It mainly comprises the phases which easily can be seen in the topographic forms of the east shores of Hudson Bay and James Bay. As we have seen it is not yet possible to date all of them with any degree of certainty.

Rather great stress has here been laid on movements of the earth crust. Compared with most parts of the continent and also of the pre-Cambrian shield they are, however, surprisingly insignificant, especially after the great post-Proterozoic folding of the Belcher Basin sediments. They are mainly restricted to a gradual upheaval and down-warping of the earth crust, and generally speaking the Hudson Bay area has been more or less stable during post-Cambrian time.

This permanence of the oldest central parts of the pre-Cambrian shield may be one of the principal factors in the origin of Hudson Bay. This question will be discussed in another connection.

Some features of the Glacial and Postglacial geology.

The pleistocene sediments.

The pleistocene sediments of the coastal region of eastern Hudson Bay and James Bay are generally thin. Rock exposures abound even where the topography is low. The hills are everywhere barren and of their earlier drift cover only accumulations of boulders remain, the more fine-grained material having been washed away by the action of the waves.

The drift cover consists partly of densely packed ground moraine, generally rich in clay, partly of marginal, surface moraine-deposits of sandy material. The latter type generally occur as ridges and small hills easily visible in the topography.

Glacifluvial deposits of assorted sand and gravel are found chiefly in the southernmost parts of the area and round the mouths of the great rivers. Deposits of great thickness occur round the estuaries of Moose River and Nottaway River, at the southern end of James Bay. Charlton Island and some of the other islands in the Bay also consist of glacifluvial sand and possibly also moraine, evidently deposited during the last stage of the glaciation.

These formations indicate where the moving inland ice stopped for a comparatively long time, during which the clay belt of northern Ontario and Quebec was deposited in the ice dammed great lake Ojibway-Barlow.

Farther north clay deposits seem to play a rather insignificant role in the coastal region except at the river mouths, where they are found underlying the delta-sand deposits.

Erratic blocks, often of considerable size, are found all along the sea-shore. They seem to be particularly abundant in regions where drumlins and other surface moraine forms are prominent in the topography. In many cases they have evidently been accumulated by the action of the sea-ice, at different levels above the present shore-line. All boulders observed by the author consisted of the rock material along the coast. Granite gneiss and basic eruptives of different kinds predominate, but proterozoic sediments are also abundant.

The influence of the glacial deposits on the topography is conspicuous only where the latter is low. In the hilly landscape between Cape Johns and Great Whale River the pleistocene deposits are therefore conspicuous only round the mouths of rivers which have accumulated great quantities of sand. The moraine cover of the valleys is generally hidden under swamps and peat-bogs. The south coast of the Belcher Basin is also generally high and only occasionally do sand deposits predominate in the topography.

Along the low coast of James Bay moraine ridges running mainly from east to west form a conspicuous feature in the landscape. These low, elongated hills also form many of the small islands off the coast. As Low has stated, they represent drumlins which have been deposited parallel with the main direction of the movement of the glaciers. They are particularly abundant between Old Factory and Cape Jones. Some of the gravel ridges in this region forming elongated islands and lying at right angles to the coastline bear a

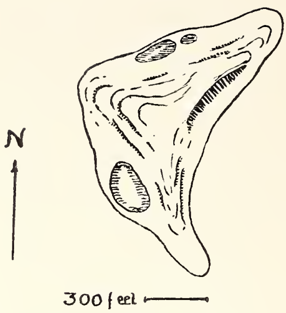


Figure 9. Esker fragment or kames south of Cape Jones.

strong resemblance to eskers and may be partly formed of glacifluvial material. This is the case with some of the ridges round the H.B.C. post of Old Factory.

Of undoubted glacifluvial origin are some of the sandy islands south of Cape Jones near the mouth of Roggan River. Here the sand ridges form eskers or kames, the most prominent features in the landscape, and are characterised by a concave steep proximal slope turned eastwards (Fig. 9).

The glacial sculpturing of the bedrock, the »roches moutonnées» and the glacial striae have already been studied by Bell and Low.

The rounded, ice-polished slopes of the cliffs are chiefly directed towards the east or north-east. The striae direction is likewise east-west to north-east — south-west. Low concluded that the movement of the inland ice during its greatest extension was east-westerly, the ice center being situated in the middle parts of the peninsula. During the last stage of the glaciation the movement was more from the north-west, indicating a displacement of the center in a northerly direction.

Tanner[1] has particularly pointed out in his studies of the physical geography of the Labrador Peninsula that the estimation of the direction of movements of the inland ice must be extremely careful because the striae mainly indicate the direction during the latest stage and especially at the edge of the glaciers, and rarely give a clear picture of the conditions during the optimum of glaciation. He puts forward the thought that during the maximum of glaciation there may have existed one single ice center in North America situated somewhere in the middle of Hudson Bay, which would give an ice movement from west to east. This hypothesis is supported by the fact that the greatest uplift of the land and consequently the greatest thickness of the ice-sheet in North-Eastern Canada is found on the east coast of Hudson Bay. This is, as Flint especially has pointed out, a natural consequence of the growth of the ice-sheet.

None of my observations have confirmed this hypothesis but it should be taken into account in future research, also concerning the crustal movements and the old shorelines.

This question might be settled by examining the directions of the glacial

[1] Compare also Flint's textbook. 1949.

striae and the erractic boulders. It would above all be worth while to ascertain where erractic blocks from the Belcher Islands are found along the eastern shore of the Belcher Basin.

Raised beaches.

All geologists and naturalists travelling along the coast of Hudson Bay have pointed out the great number of well-developed raised beaches, but until now there has been no systematic investigation or attempt to connect the strandlines in different parts of the region. These are found at every altitude as far up as the highest crests of the hills. Low therefore concludes that during late glacial times the land must have been submerged at least 700 feet above the present sea-level.

The coastal region of Hudson Bay offers, because of the absence of high mountains, no possibilities for determining the »marine limit», but the old shore-lines give ample opportunities to study the different stages of the rise of the land during post-glacial times. As in Scandinavia and Finland this movement has taken place in stages. More pronounced shorelines indicate cessation of movement or transgressions which should be visible all along the coast.

The correlation of the raised beaches requires a great number of exact measurements carried out with a level. Scattered observations are in that respect of less value because the greater part of the shore-lines are represented by boulder-walls, generally several, one above the other. Such shore-lines generally give rather inexact values if the number of determinations is small. Only where the shores are connected with gravel terraces can the exact position of the sea-level be determined. There are, however, enough areas also of the last named type which will permit the correlation of at least the more prominent shore-lines and which will give a clue to one of the less known chapters of the post-glacial history of Northern Canada. The Hudson Bay coast offers in that respect better possibilities than, for instance, the coast of Labrador where, as Tanner's investigations have shown, the climatic conditions and the vegetations are severe obstacles to a detailed study of the raised beaches and the collection of data for the reconstruction of the »spectre» of the crust movements of the north-eastern section of the North-American continent.

The older strand-lines situated more than 200 feet above the sea-level can be studied particularly well along the northern section of the east coast of Hudson Bay north of Cape Jones, where the land rises comparatively

rapidly from the sea. The islands of the Nastapoka Archipelago display well-developed raised boulder beaches in the drift covered depressions between the barren cliffs from the sea-level up to 3—400 feet. Most of these shore-walls, however, are not bigger than the pebble-walls formed by one single heavy gale on an open sea-coast, and it is so far impossible to point to any more prominent stage of stoppage in the rise of land.

Here it must be remembered that many of the strand-lines along the coast are probably not real sea-beaches but may have been formed by ice-dammed ponds. We must not disregard the possibility that the southernmost parts of Hudson Bay, and above all James Bay, have once been dammed up between the inland ice and the coast. This would be an important consequence of the assumption of one single ice-center situated somewhere in Hudson Bay. Even if so far we have too few observations supporting such an idea, the possibility has to be taken in account that some of the uppermost strand-lines may belong to ice-ponds and thus be situated far higher than the uppermost sea-level.

Some few observations from the northernmost part of the coast mainly illustrate the type of the shore formations:

At Port Harrison and the adjacent regions there are several well-developed boulder beaches which evidently represent more enduring positions of the sea-level.

On the eastern slope of the mountains north-west of the settlement (behind the wireless station) there is a small sand terrace at 178 feet. Above the terrace there is a wall of boulders resting partly directly on the gently sloping bed-rock. Owing to the action of the waves the boulders have sculptured cavities in the solid rock (granite) of the same type as is often found on recent sea-shores (Fig. 10).

Another boulder beach, where the abrasion has left still more conspicuous traces in the bed-rock (gabbro), was observed about 18 miles east of Port Harrison, about 3 miles north of Porpoise Cove (9). This shore is situated 370 feet above the sea-level.

It is evident that such shore marks formed in the solid rock will offer good possibilities for the determination of the highest limit of the wave action and furnish a definite proof of a comparatively long period of marine erosion.

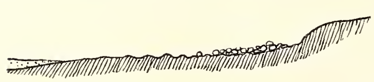


Figure 10. Shore line with boulder belt and excavation in the solid rock ground. About 1 M west of Fort Harrison, 178 feet above the sea-level.

The lower beaches formed during late post-glacial times, when the greater part of the peninsula was free from ice, have generally the character of terraces and treraceplains formed in gravel and sand.

They are particularly well developed at the mouth of the rivers. At least two systems of shore-lines can be recognized everywhere, one between 75 and 100 feet, the other between 20 and 30 feet above the present sea-level.

At Port Harrison the higher terrace, which marks the crest of the river banks at the first falls of Harrison River, lies 75 feet above the sea-level. The lower terrace on which the radio-sound station and part of the settlement on the right hand side of the river are built, is situated about 30 feet above the sea-level. The sub-fossils occurring up to the higher level represent species of more or less the same kind as we find at Port Harrison to-day (Mytilus, Saxicava, Yoldia, etc.).

At Great Whale River (14) there are three well-marked terraces in the sandy river banks.

The highest one which partly coincides with the level of the wide sandy plains around the lower course of the river is 98 feet above the sea-level. Another terrace, also very well-developed, lies at 42 feet and may correspond to the 30 feet terrace at Port Harrison. There is still one lower terrace at 24 feet which evidently corresponds to the level during the spring-high water.

Terraces which evidently correspond to the foregoing were observed in several places along the coast between Great Whale River and Cape Jones (19), Sucre Creek (15), Little Cape Jones, etc. (17).

The corresponding terraces can be seen at the mouth of the large rivers also on the shore of James Bay, at Fort George River, Roggan River (21), Beaver River and East-Main River (29); but I have too few measurements to allow any conclusions concerning the gradient of the shore-lines along the coast. In any case the sea-level during the time of the late glacial accumulation of the great sand deposits round the rivers was about 90 feet higher than to-day. As will be seen later this circumstance had a certain influence on the development of the lower course of the great rivers of the country.

The Pleistocene development of the lower courses of the rivers.

In connection with the melting of the ice there was — as we have seen — a very great accumulation of sand and silt in the old river valleys. When during post-glacial time the sea-level dropped again the rivers in many cases were forced to change their course. Such conditions can be studied particularly well in the lower course of the Great Whale River (14).

For about 8 miles from the mouth the river flows with a gentle gradient between steep sand-bluffs. Here are the first rapids formed by a threshold of granitic rocks giving rise to a number of rapids and falls. In a distance of

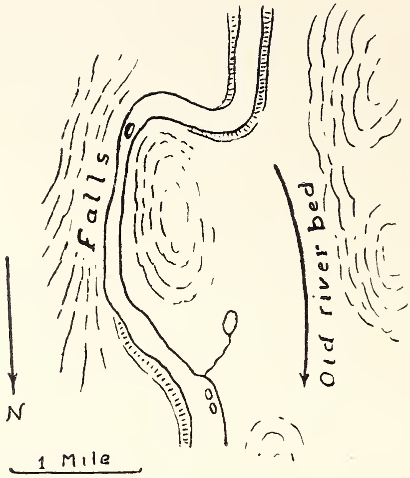


Figure 11. The bend at the first fall of Great Whale River with old river beds.

about one mile the descent is about 80 feet. Above the fall is a long stretch of calm water.

On the east side of the present river-bed there is a broad old valley separated from the rapids by a narrow ridge of archaean rocks (cf. fig. 11). This old valley is to-day filled with sand but was originally both deeper and broader. Some well-developed dry river-beds eroded in the sand-deposits in the valley can still be seen. The valley-plain corresponds approximatelyto the 100 feet river terrace mentioned above.

At the time these terraces were deposited the lower falls of Great Whale River did not yet exist. The river-mouth was where the old valley passes the present falls, and outside the mouth a great sandy delta of considerable thickness was formed. When the westerly river-bed had been filled up with sand one part of the river began to flow through the narrow gap between the hills on the east side of the river, at that time filled with gravel.

During the gradual rise of the land the erosion began to dig out new river-beds in the delta-plains, more rapidly in the eastern arm because of its steeper gradient. Very soon the old westerly arm dried up and the late erosion-valley below the Great Whale River Falls was formed.

The lower course of Fort George River (24) has evidently also during post-glacial times moved northward and the main arm now follows the northern edge of the post-glacial delta. There is however a broad, almost dry valley on the south side of the great sand plains round the river-mouth which may indicate a former post-glacial outlet.

The lower course of the Nastapoka River (10) has evidently been formed in a similar way to the Great Whale River. There are great accumulations of sand on the south side of the present outlet, accumulated while the sea-level was about 100 feet higher than now, and at least one part of the river was flowing in a straight line to the sea. The northerly bend giving rise to the high Nastapoka Fall was formed later, when the land had started to rise.

Strange enough we have the same northerly bend of the mouth in the Langland River. I had, however, no opportunity to confirm whether conditions here had been similar.

It is, of course, not surprising that there are dry riverbeds at the mouth of the rivers formed when the ice melted and more or less large displacements of the course of the rivers took place, they are evidently a more or less normal feature in the physiography of the country.

Dunes.

According to earlier descriptions of the east coast of Hudson Bay dunes are rare. Broadly speaking this statement holds good, with the exception of certain parts of the shore between Cape Jones and Great Whale River and on the sandy islands in the southernmost part of James Bay. Comparatively large accumulations of fine sand in these regions and the climatic conditions have given rise to some rather important dune-fields.

In the arctic regions in general the soil is too damp to permit any eolic erosion of importance. First in the sub-arctic zone among forest vegetation, coastal dunes become more common. As, however, the precipitation is rather high and local conditions are favorable, especially the strong winds indispensable for dune formation, there are some features of special interest. A few localities are worthy of closer study.

Most of the active dunes were noticed in the region round the mouth of the Great Whale River, where white sandy hillocks are in many places visible even from the sea. Very conspicuous is the luxuriant vegetation of Elymus which always covers the seaward slopes and which seen from a distance gives the impression of green pastures. Most of the dune sand is at times bound by the vegetation and only in certain places are there still active dunes or those of which at least one part is moving. The vegetation always has a marked influence on the shape and growth of the dunes.

The dunes on the shores of the Belcher Basin can be classified as follows: 1. Parabolic dunes (Horse-shoe dunes), 2. Transversal dunes and 3. Wind pits.

The following descriptions will illustrate the character of these formations.

Wind pits at Sucre Creek (16).

The small river, Sucre Creek, which is the outlet of some lakes in the interior, debouches about 20 miles northwest of Cape Jones. During post-glacial time sand deposits of considerable size accumulated at its mouth, on the west side

of which the gently sloping sand terrain exhibits several strandlines forming low gravel and sand-ridges. In the uppermost of these latter, which are covered with vegetation — including sparse growth of picea alba — there are a number of small piles of sand 3—4 feet in height. At each pile there is a pit with steep walls 12—15 feet in diameter and 6—7 feet deep. The piles are always situated at the end of the elongated pits and always at the north end. They give at first sight the impression of having been dug by man; but a closer examination shows that they are formed by wind erosion. The sand is to-day for the most part bound by the vegetation, except on the leeward side where the sand piles are still moving.

We have here a type of surface form caused by eolic erosion which we shall call »wind pits»[1], and which occurs on sandy ground where the soil is only incompletely sheltered by the veget. ation. A certain velocity of the wind will give rise to a little hole in the bare sand and this gets larger until the vegetation of the surrounding ground becomes strong enough to check the erosion. Downwards the erosion will continue to a depth which will depend on the diameter of the pit, the dampness and size of the sand grains. The raised sand accumulates as miniature dunes at the leeward end of the pit.

[1] Corresponding to the German »Kupsten» formations.

Figure 12. Dynes west of Great Whale River. Windward side with dead wood to the left.

Dunes east of Black Whale Harbour.

A couple of miles west of Black Whale Harbour there is a sandy neck between the mainland and a small rocky point with limestone cliffs.

On this neck there are several rows of dunes 6—10 feet high and several hundred yards in length. They have very ragged (»humpy») crests and are often isolated hillocks and wind-pits of the types described above. The greater part of the dunes is covered with vegetation and only on very wind exposed places is the sand moving.

The dunes generally run about NE-SW and can evidently be regarded as transversal dunes built up in rows. The prevailing wind — probably slightly deviated by the coastal topography — seems to have been from the south-west.

Dunes of the Great Whale River Region (*14*).

The most important dunes of the east coast of Hudson Bay are in the vicinity of Great Whale River where, as we have seen, the sand deposits are of considerable size. Beautiful sandbeaches are found along the coast both east and west of the river-mouth.

Eight miles south of Great Whale River dunes are visible from the sea with snow-white sandy slopes and green meadows of Elymus arenarius. They are situated some hundred yards from the shore on rising ground about 20 feet above the beach. The lower part of the seaward slopes, which are about 15 feet high, is hidden by comparatively luxuriant spruce vegetation.

There is here only one single row of dunes, consisting a number of hillocks with their concave sides turned towards the mainland (North). On the north side the horseshoe shaped dunes enclose small even flats from which the wind has removed all fine sand, leaving the ground covered with small pebbles.

In the deepest of these excavations there is a shallow pond, proving that here the erosion has reached almost to the ground-water level.

On the leeward side (toward the sea) the dunes are advancing into the forest which has been partly covered with sand; the trees are dying. On the windward side remnants of dead trees still standing can be seen, proving that the dunes have been making their way into the forest for a long time.

The dunes are advancing in places on a very narrow front, 100 feet broad, or less, and therefore moving forward, clearing long gates through the forest (fig. 13). These wind gates or wind furrows end in a small dune.

We here have a type of parabolic dunes formed in a region where the humidity is high enough to give rise to rich vegetation. They differ from the

Figure 13. Wind furrow (garmada) formed by dune advancing through the forest. West of Great Whale River.

normal type having no or only insignificant walls (on the flanks). Only the front is elevated above the rest of the topography. The greater part of the dune formation has actually the character of an excavation. These dune forms correspond in many respects to the »garmadas» of Hungary.

The age of the threes covered by the sand, on the north side is at least 100 to 150 years. Strangely enough there are also on the inland side, only about 200 yards from the dune walls, spruce trees of about the same size. I had no possibility to estimate the age of the dead wood in the wind pits beyond the dunes.

North-east of the mouth of Great Whale River there are several large dune fields. They are of the same general type as the dunes described above, but larger and consist of a windcleared central excavation often 900—1,000 feet in diameter, surrounded by sand ridges like the walls of a fortification. The central excavation is generally 10—12 feet lower than the surrounding ground. The dunes are highest north and west of the depression, and reach a height of 18—20 feet. The shape of one of the largest of this type is shown in the sketch map, Fig. 14.

Here also the wind erosion has reached a depth where the dampness of the ground stops it. On the bottom of the central depression shown in Fig. 14 some small springs indicate the vicinity of the ground water level (evidently somewhat elevated by the dune itself).

On the north (leeward) side of the dunes the sand covers the forest vegetation

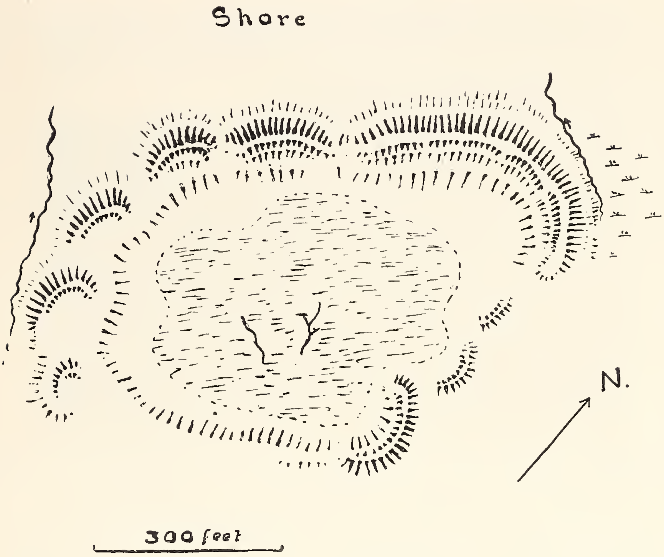


Figure 14. Horse shoe dunes west of Great Whale River with central depression reaching to the ground water level.

and dry dead wood is found on its windward side. Fig. 15 shows that the dunės are to some extent advancing over marshy ground also.

The direction of the movement is chiefly northerly or north-easterly, towards the seashore or parallel with the seashore.

The dunes of this locality can also be considered a kind of parabolic type modified by the rich plant cover. They can also be regarded as very large wind-pits of the kind described above.

Dunes and wind-erosion on the northern coast of the Belcher Basin.

In the northern, arctic, sector of the coast of the Belcher Basin there are in several places small dunes like those mentioned by Manning as at Nastapoka River (10).

Seen from the air the sand-fields have a peculiar striped aspect with long barren gates of sand, between which are narrow ridges partly covered with vegetation, running about east to west. On the photograph, they give the impression of earth flow age but I think they too must be interpreted as wind-furrows with »garmadas». The dry sandy soil makes earthcreeping

Figure 15. Dunes advancing over marshy ground North-east of Great Whale River.

less probable. As I had no opportunity to study the phenomenon on the ground I must leave this question unsettled.

In the region of Port Harrison traces of wind erosion are also strong. Dry sandy ground is generally blown bare with only small stones covering the earth.

Fairly large wind excavations resembling the central excavations of the dunes of Great Whale River are found about 3 miles east of Port Harrison, some miles from the seashore.

The climate and the dunes.

»Fossil» dunes are fairly good indications of a change of the climate from dry to wet or from more windy to less windy, and in the same way dunes whose late origin can be proved indicate a development of the opposite kind.

Besides the localities mentioned here dunes have been reported in Tanner's description of Newfoundland-Labrador from Muskrat Falls, Hamilton River. He publishes an air photograph showing old dunes, now completely covered by vegetation and situated in a marshy terrain. They are typical parabolic dunes directed toward the east indicating a predominantly westerly wind at the time of their deposition.

So far as I know there are no active dunes of any importance in the coastal region of Newfoundland-Labrador and the climate here must therefore have been formerly drier. The prevailing summer wind blows from north and north-west.

The relation between the dunes of the eastern shore of Hudson Bay and the climatic conditions, especially the winds, of the region is an interesting study.

We have seen that the traces of wind-erosion visible in these places are evidently of comparatively recent origin. There can hardly be any fossil dunes even if the vegetation has in many places bound the moving sand.

There are in any case numerous examples of wind-erosion which has only begun rather recently in places where no dunes previously existed (Sucre Creek). These facts may indicate drier conditions and possibly also increasing wind. This statement is supported by observations of the character of the timberline. In Ungava dying wood is a normal phenomenon at the timberline, indicating deteriorating conditions for the forests.

The climatic factor most directly influencing the shape of the dunes is the wind, the prevalent direction of which they clearly indicate. We have in the region of Great Whale River evidence that the dunes to-day are moving northward from the land towards the sea, which is rather strange on a coast open to an Arctic sea, even if similar conditions have also been studied elsewhere. In order to find out whether this statement can be explained by means of available meteorological data I have studied the wind-direction and the force of the wind at some stations on the coast.

Systematic meteorological observations have been carried out only at Port Harrison and at Moosonee, during certain years also at Fort George and Great Whale River. I have used the data from recent years from the first two stations, which have been kindly put at my disposal by the Meteorological Service of Canada in Toronto.

Unfortunately these stations only represent the extreme climatic types of the coast, the most northerly and the most southerly, and a close resemblance to the conditions at, for instance, Great Whale River cannot be expected. They, nevertheless, give important information which throws some light on the question of the connection between the dunes and the wind in the coastal regions of eastern Hudson Bay.

A glance at the records of the percentage frequency of the winds during the different months in different directions reveals some important variations at the stations. At Moosonee the prevalent winds during the year blow from the south, south-west and west; at Port Harrison those from the north and north-east.

Wind-erosion, however, depends not only on the direction but also on the force of the wind. Further, we must take into account the fact that the ground, during the winter months, is protected by the snow; the wind-action during

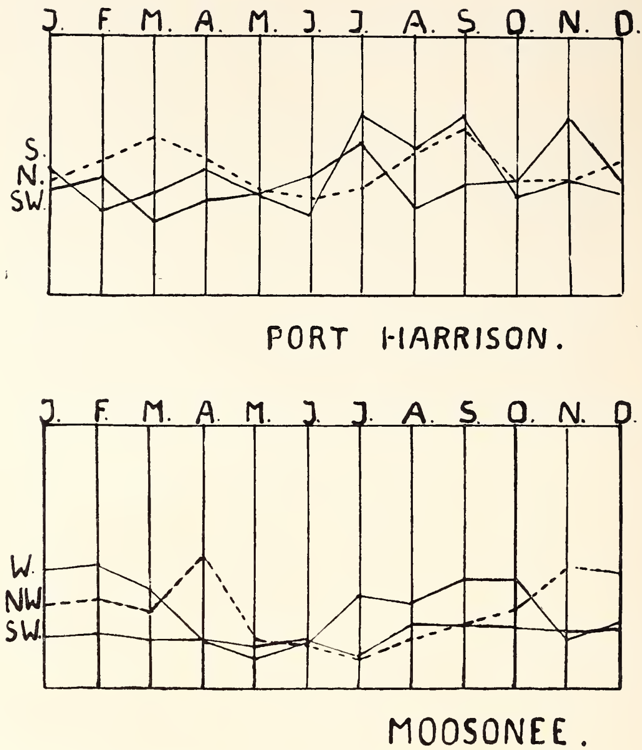


Figure 16. Diagram showing differences of wind action (Windspeed in m) hours multiplied by percen tage frequency during different months at Moosonee and Port Harrison.

that time is consequently almost nil. In order to estimate the wind-action we must, in other words, study the average direction and the velocity of the wind during the snow-free seasons. (The direction of the strongest winds during the summer.)

In order to compare the wind-action during different seasons I have used the product of the frequency and the velocity of the wind in a certain azimuthal direction. These values have been plotted as graphs in the diagram Fig. 16.

It is evident from the diagram that the most frequent and also the strongest winds during the snow-free season are actually blowing from the south and south-west, both at Moosonee and in the Portland Promontory region. In the northern regions the period of southerly winds is, however, rather short and northerly gales characterize the general type of the climate during the winter.

Probably the climatic conditions of the northern parts of the region extended formerly further south than to-day and the predominance of the southerly winds was less evident on, for instance, the south coast of the Belcher Basin during postglacial time than now.

The shape and the movements of the recent dunes correspond, as we have seen, to the present wind conditions. The south coast of the Belcher Basin is actually, during the summer season, a leeward coast, which may also to a certain degree explain the rather luxuriant forest vegetation which here extends almost to the sea-shore.

The present position of the dunes at the places described in the vicinity of Great Whale River, fairly far from the shore in spite of their movement towards the sea, may be due to a more northerly wind direction during the periods of their formation or to a very recent origin.

Arctic soils (Permafrost).

Arctic soils with permanent movements of the surface layers due to persistently frozen ground was observed already as far south as the islands of James Bay. Small gravel-ridges of silt formed by sliding were found on the shores outside Atikuan Point [near Beaver River (22)]. This phenomenon, however, seems to be restricted to the outside islands and is evidently due to the influence of the sea.

On the mainland earth-creeping is not frequent until we come to the tundra region north of Richmond Gulf. On Portland Promontory soil sliding is comparatively important. On sloping ground the earth cover is generally moving downwards, particularly if it is rich in clay. Topographic forms sculptured in unconsolidated material, like earth terraces, are considerably influenced by this phenomenon, and render difficult the determination of the exact level of older terraces and sea-beaches.

Small earth cones surrounded by pebbles are numerous and represent initial-forms of polygonal earth. Near the shore sub-fossil shells together with

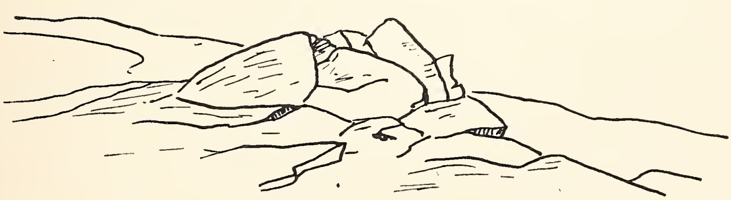


Figure 17. Cairn-like stone heaps formed by frost action. Hopewell Sound.

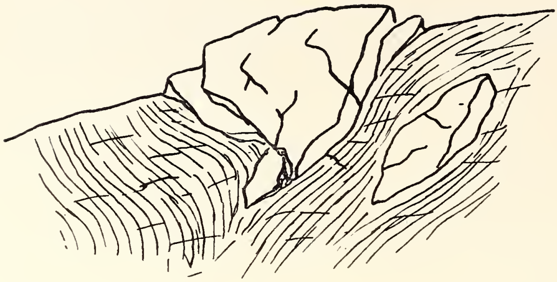


Figure 18. Gabbro inclusion in mica schist pushed upwards due to frost action. Hopewell Sound.

stone pebbles have been brought to the surface from deeper levels in connection with the earth movement.

Arctic soils do not, however, broadly speaking play the same role here as in high arctic regions, and rarely check the vegetation.

Permanently frozen ground is found at Port Harrison from a depth of about 4 to 6 feet. The only safe ground for building construction is therefore the dry sandy soil or the bed-rock.

In the solid rocks also surface forms can be observed which are obviously caused by frost action. Particularly where the rock-ground is heterogeneous and includes basic rocks in schists it is broken into fragments pushed upwards like moving ice by small movements in the superficial parts of the earth's surface. They often form small heaps of stone blocks resembling cairns made by man. Sometimes there are hundreds of such heaps scattered over a small area (Fig. 17 and 18).

The Bed-rock.

The archaean bed-rock consists for the most part of granites or gneisses, the vaguelly defined name gneiss being used for rocks of granitic composition but with an anisotropic pattern and containing portions of older rocks. These rock-types offer megascopically nothing new compared with other areas but the immense extension of very similar gneissic rocks and combinations of rocks is remarkable. The coast-line from James Bay to Portland Promontory, more than 100 miles, represents the cross-section of an area of extreme monotony so far as the rock-ground is concerned and, according to the conservative definition, could be characterized as one single granite-batholite containing inclusions of older rocks.

As Low pointed out more than fifty years ago there must be a considerable percentage of sediments and other supercrustal rocks even in the areas of seemingly pure granites, but all the components of the rock-ground are in

most places so thoroughly mixed with each other that it generally is impossible to distinguish their limits. They appear as one single cast with a more or less coarse-grained structure which evidently arose during the same last period of recrystallization.

The principal elements found in varying proportions are as follows:

1. Light pink colored or white microcline-granite. The texture varies from coarse pegmatitic to rather fine-grained, often also with pseudo-porphyric augen-gneiss-like structures. The general aspect is in most cases schliry with unevenly distributed dark minerals. Only exceptionally are larger areas of homogeneous granite met. Pegmatite and aplite-veins are numerous.

2. Lime-sodium gneiss with compositions varying from lime-sodium granite to diorite. The rocks are medium-grained, generally even-grained, but with a distinct parallel orientation of the dark minerals. The colour is light gray to dark gray. The rock is older than the microcline granite and occurs as inclusions in it.

3. Basic plutonic rocks of gabbro-composition play a certain role, particularly in the northerly region (Portland Promontory).

4. Supercrustal areas where primary structures indicate the original character of the rock-types, containing both former sediments and effusives, have been found only exceptionally. Some few occurrences, however, provide evidence that the greater part of the dark inclusions in the gneisses may derive from primary basal rocks of this kind.

5. Vein-gneisses of different kinds consisting of a mixture of granitic material and schists, generally folded in a very plastic state.

6. Basic and ultrabasic angular inclusions in the gneiss, often of pyroxenite, hornblendite or soapstone.

7. Young basic dykes cutting through these rocks (mentioned above) are found all over the area. They generally have more or less vertical contacts with chilled margins. The texture is unaffected by later recrystallization. The petrography of these dykes, of which the composition varies from pyroxenitic to diabasic, will not be described in greater detail.

It is evident that they represent proterozoic intrusions filling the vents of the lavas interbedding and overlying the late pre-Cambrian sediments.

The photographs Fig. 23—30 give a better general picture of the rock-types than a description. They illustrate a type of rock-ground familiar to everyone who has been in touch with archaean regions and found everywhere within the deeply eroded parts of the pre-Cambrian shields of the world.

The petrological data concerning the rock types from eastern Hudson

Bay at present available. are restricted to scattered points. On account of the monotony of the bed-rock they nevertheless make it permissible to draw some general conclusions from the information at hand.

The basal formation of Portland Promontory.

A number of localities visited in the summer 1947 will now be briefly described, beginning with the northernmost region at Portland Promontory where certain elements of the basal formations can still be recognized.

The best key-district to the geology of Portland Promontory is a region about 8 miles in diameter situated on the mainland north of Frazer Island at Hopewell Sound (9). On Low's map the bay, east of which are the formations now to be described, is called Porpoise Cove. The dark colour of the cliffs and the rusty weathering show at first glance that the rock-ground here does not consist of the ordinary gneisses.

It consists of a series of strongly metamorphosed schists, partly of sedimentary, partly of volcanic origin. For the sake of convenience it will be called the Port Harrison series after the only white settlement of the district. The formation seems to form a complicated syncline (about 5 m in diameter), the layers of which have been overfolded towards the west. The axis of folding, which can be determined by both the strong differential folding and also by a lineation coinciding with folding-axis, dips 30—40° to the south. The rocks have been strongly affected by tectonic deformation and the greater part of the members are definitely schistose.

Crossing the formation from its westerly contact eastwards, a couple of miles north of Porpoise Cove, the following sequence was found:

West of the contact the base consists of an almost white gneissic granite with about 50 % albite and 40 % quartz and chloritized biotite in small flakes representing the principal mafic components. Accessory constituents are magnetite and apatite in small quantities. A comparatively high content of zircon is a typical feature of the rock. Secondary constituents are small quantities of muscovite and epidote. The granulated texture and a slight parallel orientation indicate that the rocks have suffered a certain tectonic deformation which, however, is not visible in all samples and which seems to be stronger near the contact with the schists. The contact surface is almost vertical and nowhere sharp. The increasing amount of dark minerals in the gneiss near the boundary indicate an assimilation contact.

The lowest horizon with non-gneissic composition is an ultra-basic rock mainly consisting of serpentine-soapstone occurring as lens-like bodies or sheets

along the contact. A certain percentage of pyrrhotite and pyrite gives the rock its red rusty weathering. Veins of antigorite and especially flaky chlorite cutting the dense main mass of the rock are abundant.

Under the microscope the rock displays a network of rather large fibrous xenomorphic actinolite crystals in a matrix of serpentine and chlorite. The crystal boundaries are mostly sharp and the minerals evidently are in equilibrium. The chief part is a very fine-grained mass of serpentine with small grains of magnetite, sulphides and evidently also some talc. Olivine and pyroxene were not detected in the thin sections studied.

Above this greenstone horizon which has a thickness of 8—900 feet there is an iron-bearing layer — sometimes within the greenstone horizon — consisting of magnetite and partly serpentinized hypersthene with abundant quartz. It has for a distance of about 2,500 feet the character of a low grade banded iron ore resembling the Keewatin ores of central Ontario. The greatest thickness was about 30 feet. In the southernmost part of this iron formation there is rather much ferruginous carbonate and red chert.

The next horizon consists of impure quartzite up to 400 feet thick. Then follows a hornblende-biotite schist of varying composition, above which there is a thin layer of white quartzite-like schist consisting of fibrous, firmly parallel orientated actinolite and antophyllite, plagioclase and some biotite. The orthorhombic amphibole generally occurs as an outer zone round the actinolite needles, but also as independent crystals. The plagioclase is mostly clear, but in some grains epidotization is found.

The central part of the syncline consists of hornblende-mica schist generally with rather much diopsidoic pyroxene, alternating with layers of micaceous schist and layers of hornblende-diopside gabbro. This last is particularly abundant in the more peripheric part of the formation.

All the rock types, except the ultrabasic, have structures which bear witness to strong tectonic deformation giving rise to shearing and small-foldings; the latter being particularly conspicuous in the central parts of the series.

The youngest rock in the region is a white pegmatite occurring as large dykes mostly following the schistosity, but also sometimes forming cross-cutting dykes. They consist almost exclusively of gray potash-felspar often with graphic structure but also partly of technical quality, and white glassy quartz. The texture is unaffected by the strong tectonization of the shists, proving that the rock intruded later.

The Port Harrison series has evidently to be interpreted as a volcanic formation with interbedded sediments, whether of normal sedimentary origin

Figure 19. Weathered soapstone cliffs N of Port Harrison. Hopewell Sound.

or pyroclastics is difficult to decide on account of the strong alteration. The actinolite-antophyllite schist may possibly be a metamorphosed impure limestone or limy sandstone. The ultrabasic rocks could, so far as their texture is concerned, be of hypabyssal origin. The presence of stratified iron-ore, however, rather points to a superficial deposition of the rock.

The next locality of interest for the understanding of the archaean rockground of the neighbourhood of Port Harrison is a small island outside the mouth of *Five Mile Inlet,* a long fjord west of Port Harrison (Fig. 19).

The shore-cliffs west of Port Harrison consist of very light-coloured granitic gneisses with occasionally some dark angular inclusions. These inclusions are more abundant westward. At Five Mile Inlet they form large eruptive breccias. On this island there is an area some hundred feet in diameter which consists of a dark basic rock penetrated by aplitic dykes. The former is fine medium-grained, with xenomorphic granular texture and no visible schistosity. The composition corresponds to a gabbro with labrador-andesine and pigeonite-diopside as its main components. Both minerals occur in about equal proportions (45 %). About

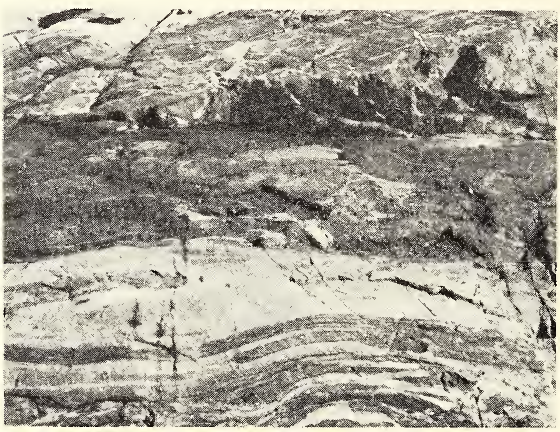


Figure 20. Contact between garnetiferous skarn and aplitic gneiss. Five Mile Inlet W of Port Harrison.

10 % of the rock is light yellowish brown biotite. In some sections there are also varying quantities of greenish-brown hornblende, formed at the expense of the augite. A little magnetite and apatite are accessory minerals. In the intergranular spaces there is always some talc and serpentine.

This composition seems to be very common, possibly the commonest in the basic inclusions of the region but the content of amphibole and serpentine varies.

At the south-east end of the island there are, in the basic rock, remnants of a highly folded banded iron ore of the same type as was described from the Porpoise Cove region. Remnants of the same ore, but in a highly metamorphosed state are also found in the northern part of the area, here as skarn-rocks with an abundance of red garnet and coarse crystalline pyroxene and biotite (Fig. 20). The granite, at the contact of which the skarn-rock has been formed, is pegmatic with albitic plagioclase and microcline as the chief minerals.

The pyroxene is ortho-rombic (hypersthene) with absorption from grayish-green to light pinkish. The optical properties are anomalous owing to fine orientated plates vidently due to exolution and also a slight tectonical stress. The mineral in such cases shows no complete extinction, and has anomalous interference colours. The cleavage parallel with 100 is well developed. The skarnrock also contains magnetite which seems to have crystallized later than the pyroxene and garnet, forming twisted fillings of the interstices between the other minerals. In this rock also there is generally a slight serpentinization which has affected the pyroxene and the garnet and consequently is of later origin than the former.

Greenstone altered into soapstone is also found and especially as a large inclusion in the aplitic gneiss at the south point of the island. The rock is grayish-green and very dense. Towards the gneiss there is a zone, some inches thick, consisting of coarser crystalline material rich in chloritized mica. Under the microscope the rocks show a very fine fibrous mass of serpentine and talc, with big flakes of mica which, owing to chloritization, appear to be for the most part optically isotropic. Farther there is an abundance of carbonate — calcite or dolomite —, indicating the presence of CO_2 at the alteration.

The third locality where the same formation was studied, is the north-west point of the peninsula south of the mouth of Portage Bay (2) at the western extremity of Portland Promontory. Here also we find a strong, rusty-looking weathering of the shore cliffs. The distribution of the rock types is schematically shown on the sketch-map Fig. 21. The westernmost point consists of gray, schlieric gneiss partly pegmatitic, which is followed by a series of ultra-

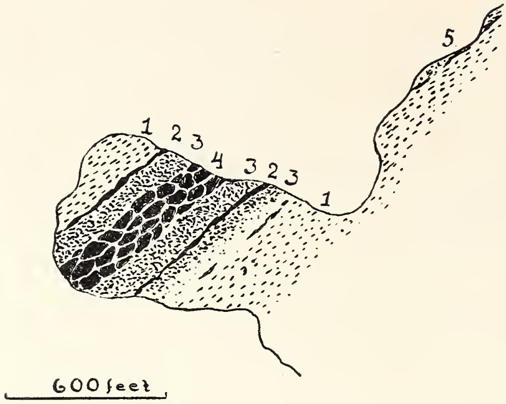


Figure 21. Sketch map showing the rock-ground of the south point at the mouth of Portage Bay. 1. Gneiss. 2. Skarn. 3. Gabbro. 4. Serpentinized gabbro.

basic rocks; between these and the gneiss there is a band of highly altered ore with both sulphides and magnetite, but especially coarse-grained garnet and pyroxene; the latter being here also rhombic. Further this skarnrock contains brownish hornblende and mica with varying quantities of felspar and quartz. The following zone of basic rock is a megascopically dark greenish densec metagabbro, highly serpentinized but yet showing under the microscope unaltered augite and some plagioclase. The rock is traversed by a peculiar network of pegmatite-like dykes giving rise to a structure resembling pillow lava (Fig. 22). The veins consist of diopside and plagioclase as chief components altering into actinolite. Consequently they seem to be derived from the same basic magma as the main body of the basic rock and not from the surrounding granites. The contacts of the veins are composed of light greenish actinolite and serpentine.

Figure 22. Gabbro pegmatite dykes in gabbro. The mouth of Portage Bay.

At the eastern border of this rock there are some bands of iron-ore which do not show any primary stratification. Megascopically they seem to consist of compact magnetite, but the microscope reveals considerable quantities of ortho-rhombic pyroxene mixed with the magnetite. Along the shore farther eastward similar magnetite layers are transformed into

garnet-pyroxene-hornblende skarn forming lumps in the migmatite-gneiss.

In spite of the very varying outer appearance there can hardly be any doubt that all these iron-ore fragments belong to the same formation.

Remnants of what is evidently the same iron formation in a still more advanced stage of alteration were observed in the vicinity of Port Harrison (7), on the hills west of the bay, where the post of the Baffin Trading Co. is situated. Here one finds very strong weathering in the rocks which at first glance give the impression of weathered peridotites. A closer examination, however, shows that most of the rock which lies in the gneiss is garnetiferous and also contains much quartz and some felspar. Under the microscope it proves to consist of rhombic pyroxene, plagioclase, garnet, quartz and varying proportions of magnetite and pyrrhotite. In basic inclusions the following mineral association was found: Klinoenstatite, ferrotremolite and actinolite represent the chief components; the minerals mentioned in the order of crystallization. Minor constituents are quartz, plagioclase, microclineperthite and biotite. There are also ultrabasic sections which are more or less completely altered into soapstone.

Basic rocks of a composition corresponding to gabbro and evidently belonging to the same series which in some places is iron-bearing are widely distributed as fragments, generally small in size, within the hybrid gneisses of the Portland Promontory. On the geological map of Low and Bell they are marked as dykes following the general strike-direction of the region. So far as I have seen, these »dykes» are rarely continuous but rather represent bands of inclusions cut by the neighbouring granitic rock. As Low has reported from the Cape Smith area they are often pinched out and disappear into the gneiss. Probably the inclusions of the gneisses represent basic rock-types of a different age but so far it is impossible to make any more detailed subdivision.

In several exposures I have observed a foliation which may be of primary origin but which also can be interpreted as secondary (deformation banding). The composition is in most cases the same as in the types mentioned before; with diopside and anorthite-rich plagioclase as the chief components and varying quantities of biotite, magnetite and brownish hornblende.

Of the basal formation, as wee sea, mainly some basic remnants still can be recognized, the rest evidently beeing gneissified.

The gneissic and granitic rocks of Portland Promontory.

A strict distinction between the granites and gneisses of the region is hardly possible and the character of the rocks appears most clearly if we say that in hand-specimens they show all the properties of a granite but in the exposures have the aspect of a gneiss.

The dominating rock of Portland Promontory is a light-coloured, often almost white, gneiss of slightly irregular texture, varying between pegmatite and fine-grained aplitegranite. Felspar and quartz are the dominating components, the mafic components playing a subordinate role except in exotic inclusions. The felspar may be microcline or albitic plagioclase — usually both. Angular or schliry fragments are found almost everywhere, indicating the rock's hybrid character.

We can distinguish a number of types of gneiss each of which reflects a certain petrogenetic history.

1. Microcline aplite gneiss (leucogranite) is a particularly typical member of the rock association of the south shore of Portland Promontory. Good exposures of considerable size are found east of the Radiosound station of Port Harrison in the slopes of the barren hills behind the station. The rock which shows a beautiful parallelipedic cleavage is almost white, rather fine-grained and resembles megascopically quartzite. A fine parallel striation caused by minute grains of biotite arranged in rows contributes to this impression.

Under the microscope the rock turns out to consist of about 55—60 % of microperthite and 30—40 % of quartz. The texture is very characteristic with an extremely crenated boundary between the mineral grains, often causing a poikilitic intergrowth of different minerals. Myrmecite is rather abundant. The very subordinate mafic constituents are represented by minute dark greenish brown biotite flakes in small clusters. They have often beside them a brownish iron mineral resembling an iddingsite, or some other chloritic mineral of the same kind. Magnetite and apatite are present in small quantities. There are always traces of a certain tectonic influence as a slight cataclastic texture.

West of Port Harrison (1) the same type of aplite-gneiss contains small grains of garnet arranged in rows, evidently indicating more alumina-rich layers. The quartz content is here so high that the idea of a granitized quartzite comes to one's mind. The rock may be a former quartzitic sediment which has been enriched in potash-felspar by means of a metasomatic addition of alumina and potassium. The textural features point to a gradual replacement

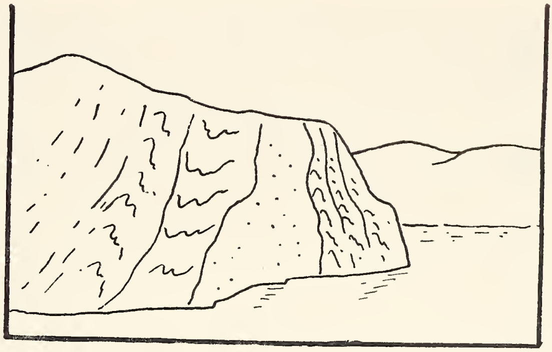
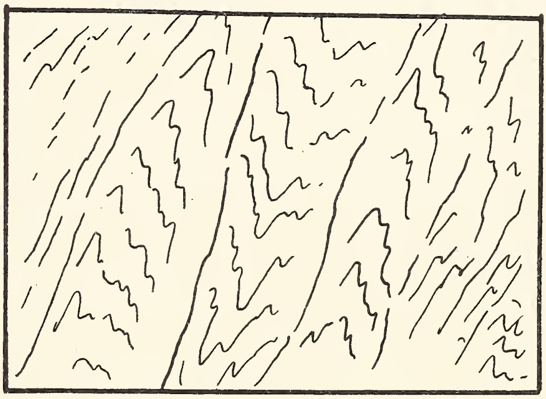


Figure 23. A. Outcrop showing folding and thrusting. The exposure is traversed by pegmatite dykes parallel with the thrust. Port Harrison.



B. Strongly folded and sheared gneiss with incipient flow structure. Hopewell Narrows.

of quartz and also plagioclase by microcline. Low often mentions gneissic rocks which he believes to be altered quartzites, but as he gives very few data concerning Portland Promontory it is difficult to judge if he also includes rocks of the type here in question. Probably he rather refers to the banded gneisses occurring as inclusions in the granites.

Strong support to the idea of the sedimentary origin of many of the gneisses in the region is given by the definitely banded quartz-rich gneisses of the shore cliffs at Bear Track River (1) at the western extremity of the Promontory. The rocks are composed of alternating strata of predominant quartz and strata rich in garnet and mica. The very regular banding here can hardly be interpreted in any other way than as a primary bedding, which has been still more accentuated by a later tectonic deformation of the rock.

Concerning the aplite-gneisses of Port Harrison a number of objections can be raised to the theory mentioned above. These aplitic rocks incontrovertibly behave like intrusive rocks forming dykes and enclosing angular fragments of older rocks which have moved within the gneiss at the same time as the flowage. On the other hand there are also transitions between the homogeneous aplitic rock and banded gneisses.

Some observations will elucidate the origination of the gneiss-formation and explain the peculiar sugar-grain-like texture of the aplites.

Figure 24. Migmatite consisting mainly of gabbro-dioritic inclusions in microcline granite. Young diabase dyke and pegmatite dyke. Port Harrison.

As an example of the movements within the gneiss at a stage when the original banding is still easily visible we can take the exposure shown in Fig. 23 A, situated about 4 miles up the river from the settlement of Port Harrison. The banding is the same as is general in this kind of rock, with biotite and hornblende — probably also pyroxene — defining the structural pattern of the rock. The gneiss is strongly folded but at the same time cut by a series of old thrust zones. Veins of pegmatite-granite cut the rock conformably with the shear-zones due to the thrusts.

A more advanced stage of deformation which started according to a similar Fracture deavage pattern is shown by Fig. 23 B, representing an exposure on the shore of Hopewell Sound a little east of the Narrows. The cross-shearing is here very strong and the texture of the rock definitely cataclastic grading into mylonitic. This rock merges into a fine-grained gneiss where the banding is still visible as a diffuse flowage, very much resembling that of contorted marble. This change has happened contemporaneously with a fresh crystallization of the microcline, and at the same time evidently a destruction of the mafic components. These latter are in the gneisses with a less advanced alteration, hornblende and biotite, in the more granitized types chloritized biotite and small grains of pink garnet.

In this way leucogranites can be formed by a combination of tectonic deformation, which contributes to the homogenization of the rock, recrystallization and addition of potassium-felspar. This of course does not mean that all »leucogranites» in the region are formed in the same way but it shows conclusively that they can be formed at temperatures below the melting-point of the rock. They also show that a high plasticity with flowage and intrusion phenomena does not necessarily mean a molten stage.

2. P e g m a t i t i c g r a n i t e or gneiss has already been mentioned several times. These schliry, unevenly grained gneisses compose in most

places the main mass of the rock ground. They belong genetically to the same group as the foregoing gneisses and may have originated with their continuous recrystallization.

3. Lime-soda gneiss granite with more or less homogeneous composition and pronounced parallel structure represents an older group of granitic rocks occurring as inclusions in the former. The rock is, particularly if strongly weathered, considerably darker than the microcline-rich gneisses but there are also transitional forms between them.

The mineralogical composition in thin sections from different localities is more or less the same. The chief components are albitic plagioclase (An 12) forming about 40 % of the rock, quartz (30 %), biotite and generally some augite and green hornblende. This last is formed by the alteration of the augite which is often found as a remnant in the hornblende. The plagioclase is always partly saussuritized with rounded grains and resorbed edges, indicating a certain degree of rotation. The augite (diopsidic) is light greenish or colourless and often altered into chlorite and mica. Only the hornblende, which is present occasionally, and quartz are without traces of alteration. The quartz generally shows undulatory extinction.

The normal gneiss-granite seems to represent a tectonically deformed plutonic rock which has intruded during the later stage of the tectonization of the basal schists. Several varieties belonging to the same series can be distinguished, of which the most important are quartz-dioritic and dioritic rocks possibly representing transitional forms between the lime-soda gneiss-granite and the gabbros mentioned from the Porpoise Cove region.

Coarse-grained pegmatite-like rocks of about the same composition have also been observed. To them belongs the coarse greenish granite found on the crest of the hills west of Port Harrison. The rock is characterized by a greenish albitic plagioclase affected by a slight tectonization which has given rise to a texture resembling the so-called birds-eye texture of the biotites. It is due to a fine fissuring in the rock to which evidently the greenish irridescence is due. Other components are quartz and light green augite and varying quantities of mica.

4. To the older components of the gneissic rock-ground we still have to reckon the banded gneisses, often with a bluish gray colour, consisting of quartz-rich and mica-rich bands, sometimes with hornblende. They grade into common vein-gneisses of the type found in all migmatite areas. On Portland Promontory they generally occur as rather small inclusions in the microcline-gneiss.

5. Mafic inclusions in the gneisses. In connection with the old

Figure 25. Inclusion of gabbro in migmatite gneiss (quartzitic), with reaction zone of rhombic pyroxene.

supercrustal and adherent formations the »basic» inclusions in the rock-ground have already been mentioned. They are, however, such a typical feature of the gneissic rock-ground itself that we must mention some facts concerning them.

The angular fragments of different sizes seem to be particularly abundant and above all sharply limited in some aplitic varieties of the gneiss, without any transitional zone between the included rock and the fragment (Fig. 26). The mineralogical composition of the latter corresponds to the metamorphic greenstones already mentioned with basic plagioclase and diopside as its chief components. Hornblende plays a subordinate role so far as can be estimated by the observations made. It is, however, in the field often difficult to distinguish the pyroxene from hornblende and the dominating role played by the first named was actually first detected at the laboratory examination of the rock collections.

Soapstone inclusions play an important part. Isolated blocks of considerable size are often found in the aplitic granite in the region of Port Harrison. At the contact with the granite they generally have a zone of actinolite and mica in radiating fibrous crystals. The actinolite also seems to be always serpen-

tinized to a certain degree. In the central parts of the soapstone inclusions seams of chloritized biotite and chlorite are common.

Of particular interest is a series of basic inclusions at Bear Track River (1) where the major part of the rock-ground consists, as was mentioned earlier, of banded, quartz-rich gneisses, evidently of sedimentary origin. The fragments, of which one is shown on Fig. 25, consist of a central part surrounded by a marginal reaction rim. Fissures of the same material cut the inclusion. Microscopical examination shows that the kernel consists of the same gabbrolike rock which we have described before from several localities, with diopside, plagioclase and some mica as dominating constituents. The reaction rim consists almost exclusively of hyperthene. A slight serpentinization is visible both in the central and in the peripheric parts of the inclusion.

Figure 26. Basic inclusion in gneiss, which has been broken and the fragments slightly removed at the flowage of the gneiss. Port Harrison.

This reaction between the gneiss and the basic inclusion is very interesting and offers a good example of a kind of basification of a rock by the removal of the felspar component (see p. 51). Augite has been transformed into hypersthene and anorthite by means of the addition of silica.

Basic inclusions of more complicated composition have also been observed. At Polly Inlet (4) at the narrowest part of the strait there are in the migmatite gneiss pegmatitic breccias with inclusions consisting of about 50 % of biotite, together with diopsidic augite and orthorhombic pyroxene. The hypersthene is partly serpentinized but the diopside is almost unaffected.

The Archaean bed-rock of the coast section between Portland Promontory and Cape Jones.

The northern section of the coast between the eastern part of Hopewell Sound and Great Whale River was seen by the author only from the air, and even the earlier reports report only a few scattered observations from this region.

There seem, however, to be very few variations in the rock composition. Uniform homogeneous gneisses dominate the rock-ground. Only north of Langland River is there a more pronounced striation of the gneisses, indicating traces of basal schists.

The rock-ground round Great Whale River can evidently serve as an example of the rock-ground of at least the southerly part of the coast section and will be briefly dealt with here.

Great Whale River (14) has been visited by several expeditions who, however, have devoted less attention to the local geology which offers only a few problems of interest.

Broadly speaking the rock-ground has a granitic or gneiss-granitic composition with predominant potassium-rich rock types. They are rather heterogeneous and have many inclusions, generally small in size. Aplitic and pegmatitic veins and dykes are numerous.

The normal rock type is a light pink or whitish medium or coarse-grained rock with perthite, oligoclase, quartz and biotite. The texture is xenomorphic granular with slight traces of cataclase and generally some myrmecitic portions between the felspar and the quartz. The microline shows a strong grind twinning the plagioclase (An 10) generally is slightly altered and has resorbed edges towards the microcline. The biotite is in some sections strongly chloritized. Often there is also a secondary crystallization of epidote and calcite. Titanite, magnetite and apatite are found as accessory components. In one case also fluorite was detected in the thin section.

The proportions of these components evidently vary considerably in different places. The more plagioclase-rich sections probably represent highly altered fragments of an older lime-soda granite which to-day can hardly be distinguished from the injected microcline-granite. By means of a metasomatic addition of microcline it has been altered into microcline granite gneiss. In general the potassium felspar is predominant in the rocks.

There are no older schists of volcanic or sedimentary origin in any regions of importance. The basic inclusions resemble, in so far as their outer appearance is concerned from those of the region already described but, studied under the microscope, they show certain differences. Soapstone does not play the same role, and the ultrabasic inclusions consist of light green hornblende and biotite. The hornblende is a little fibrous and contains minute grains of iron-ore arranged in small accumulations and rows in a way indicating a primary crystallization of pyroxene later transformed into hornblende. In a few cases highly resorbed and altered remnants of augite were observed. Plagioclase is absent or only very subsidiary.

The soapstone inclusions (observed in the shore-cliffs north-west of the post of Great Whale River) consist of serpentine talc, calcite, chloritized biotite and an ironoxide pigment. In one case also black needles of vesuvianite were found as the principal component, together with pink orthoclase forming

Figure 27. Migmatitic breccia. Amphibolite inclusions in aplitic granite. Goos Island, James Bay.

minute veins in the fragment. In this case the primary rock might have been a limestone which has been completely silicified.

Between Great Whale River and Cape Jones the archean rockground offers very little of interest and has the same aspect as from the former down to the vicinity of Cape Jones where the composition is more varied.

On the mainland west of Cape Jones (19) white migmatite gneiss with dark inclusions prevail, consisting of albitic plagioclase, quartz hornblende and biotite with remnants of light greenish augite. Microcline is subsidiary or is lacking. The yellow biotite often occurs as bands in the interstices between the other minerals and is consequently of later origin. At Little Cape Jones (17) microline is already the dominating felspar and evidently increases in importance in a northeasterly direction.

The rock-ground of the little peninsula of Cape Jones has a rather mixed composition. The dominating rock is a light gray or white granite-gneiss consisting of about 45 % albitic plagioclase, 15 % quartz and 10 % biotite and consequently corresponds to the rock mentioned above. Microline is rare, but muscovite is found in some thin sections. Calcite is rather abundant both as a fine pigment in plagioclase or as compact grains.

This granite contains inclusions of and traverses a darker gray granodioritic rock with about 65 % plagioclase, and also some quartz, biotite (15 %) and generally very much calcite. The composition of the plagioclase is An 10°. There are also coarsegrained pegmatitic varieties, sometimes with green plagioclase.

The mutual relations of these rocks and their proportions are difficult to determine from the observations carried out by the author.

Of the numerous dark inclusions at Cape Jones the most conspicuous are those composed of skarn-rocks due to the alteration of an iron formation of the type described from Portland Promontory. The original iron ore

was found only in one inclusion in gneiss, about 15 feet in length, which is situated near the south shore of the point, a little west of the portage. The rock is a highly folded banded ore composed of quartz-bands alternating with bands rich in very fine-grained magnetite. The iron-oxide occurs partly as pseudomorphoses from a flaky or fibrous mineral which could not be determined.

The formerly larger distribution of the ore formation is indicated by numerous inclusions of multicoloured skarn-rock composed of dark green pyroxene, bright green epidote and red garnet often in big crystals and further quartz and felspar. A certain amount of stratification is still shown by the arrangement of the minerals.

Under the microscope the pyroxene proved to be a light greenish hedenbergite. As to the garnet, at least a great part of the dark brownish minerals termed garnet in the field in actually an iron olivine. Other constituents in the skarn-rocks are quartz, calcite and titanite and a little bluish alkalic hornblende.

The skarn layers often show traces of tectonical deformation which has given rise to a boudinage-structure. Generally the formation is so injected by granitic material that there is no possibility of following the structures over great distances.

Besides the skarn there are also inclusions of hornblenditic composition and soapstone.

This is of great interest because it proves the former great extension of iron-bearing sediments during archaean times in the north-eastern part of Canada even in regions where to-day granitic rocks predominate.

The east coast of James Bay.

The east coast of James Bay is, so far as the archaean rocks are concerned, a little better known than the Hudson Bay coast, but even from here only scattered observations have been published. The general aspect of the rock-ground is very much the same as farther north, with gray and pink gneisses as the chief components and dark schists and basic igneous rocks as fragments.

I was able to make only a few landings and from these some observations will be briefly reported.

Outside Attikuan Point (22), there is a low island for the most part covered with glacial drift, which has been called Goose Island. The shore cliffs at the south end consist of a coarse hornblende microcline granite with abundant basic inclusions. It has in parts a porphyric texture with phenocrysts

Figure 28. Breccia structure in migmatite grading into flowstructure. Island out west of Fort George.

measuring about $^1/_2$ inch in length. Where the rock has been affected by tectonic deformation the crystals have been drawn out, giving rise to augen-gneiss.

The contact relation with the older fragments makes it probable that the texture originated in connection with recrystallization and an addition of potassium-felspar. The big microcline crystals are of crystalloblastic origin.

The inclusions forming eruptive breccias (Fig. 27) are particularly resorbed within the pseudoporphyric granite and in parts only small agglomerations of black hornblende crystals remain. Blastoporphyric crystals of microcline are numerous. The composition is in most cases hornblenditic or amphibolitic. Ultrabasic inclusions consisting of soapstone surrounded by a shell of radially orientated, fibrous actinolite and mica were also observed.

North-west of the mouth of George River there is a small group of islands which, after the nearest point on the mainland, are called Goose Point Islands (24). (One of them may correspond to Low's »Governor Islands».) The northernmost of these islands consist of light pinkish aplite gneiss, characterized by a strongly sheared structure and a well-developed linear schistosity pinching gently eastwards.

The microscopic texture is xenomorphic granular, rather fine-grained but without cataclase. A strong movement contemporary with the crystallization is indicated by a whirl-like agglomeration of the mafic minerals. The mineralogical composition is microline, quartz, plagioclase (An 10 %), biotite, épidote and calcite. These last three minerals together with some magnetite and apatite form the whirls. In the plagioclase the twin lamellation is almost visible, but is indicated by the distribution of minute inclusions.

Farther south on the neighbouring island the same gneiss occurs on the north shore but it merges farther south into less deformed gneisses where the original rock components are still visible (Fig. 28).

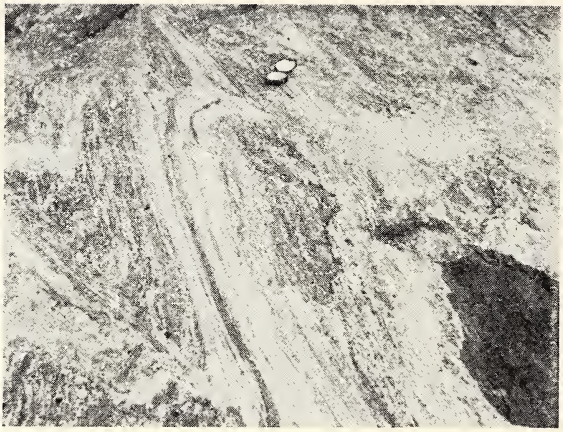


Figure 29. Flow structure in gneiss with new-crystallization of hornblende. Island near Kakishuan Point. James Bay.

The chief rock here is a gray even-grained gneiss-granite with black spots of newly crystallized hornblende which is absent from the deformed gneiss. The gneiss is cut by veins of a pink microcline-aplite.

The strong deformation studied in the previous locality, has here affected only certain zones which are characterized by the gentle plunge of the lineation. In the sections outside these zones the pitch and the axes of the small folds are very steep, as is the rule on the west shore of James Bay. The different stages of the deformation are illustrated by the photographs Fig. 28.

On a small island near Kakishuan Point (23) (outside Bald Bay) the rock-ground consists of a gray vein-gneiss with a beautiful flow structure which was evidently formed by means of a syntectonic injection of microcline-rich material in old schists and gneisses (Fig. 29). At the new crystallization hornblende crystals originated abundantly. In this gneiss there is a large number of inclusions of partly skarn-like rocks consisting of pale diopside red garnet and quartz, occasionally also small remnants of limestone, partly of coarse-grained hornblendite. Other inclusions consist of a fine-grained mixture of pale green hornblende with a pigment of magnetite and serpentine. These last inclusions have a rim of radially orientated actinolite needles of the kind previously mentioned (Fig. 30).

There is reason to believe that the hornblendites were formed by means of silicification of limestone.

The eastern shore of James Bay farther south shows an increasing amount of banded gneisses and homogeneous gray gneissgranites, all cut by pegmatite dykes. Basic rocks play a less important role as fragments in the gneiss, but are in larger complexes.

Low has described a complex of altered basic rocks from Paint Hills (26) which exhibit all transitional forms from a diabase to a greenstone-schist.

Figure 30. Inclusions of hornblendite with reaction zone of actinolite. Island near Kakishuan Point. James Bay.

These rocks, which are found on the islands outside the coast, are cut on the north side of Walrus Island by a remarkable syenitic rock which offers some interesting features.

It is the only rock type of the coast which has the homogeneous aspect of a normal eruptive rock, though on the other hand here too we have to take into account the possibility of hybrid origin. The structure is coarse-grained and is conspicuous on account of its densely packed large tabular phenocrysts — up to 1 inch in length — of very lustrous felspar. The flat section is always parallel and gives the impression of a kind of sedimentation. The composition is perthitic (microclineperthite) with almost the same percentage of albite and microcline. In many crystals the albite looks like chess-board albite. Between the big phenocrysts there is a fine-grained matrix composed chiefly of albitic plagioclase, the grains generally arranged radially round the former. Microcline also occurs in the interstices. The coloured minerals with a subordinate role are bright green pyroxene, without pleochroism with $c{:}Y = 32°$. These grains are often surrounded by small needles of bright blue alk. amphibole. Further there are small quantities of greenish biotite, epidote titanite and magnetite and calcite. The mafic component does not form more than about 4 % of the rock, the phenocrysts about 60—70%.

This syenite contains inclusions more mafic in character, of which the most conspicuous are almost pure black biotite in big flakes. Evidently these fragments of older basic rocks have arisen from a very strong addition of potassium and water to diabasic fragments in the syenite. The small amount of calcium present has been removed and probably been partly transformed into calcite, but especially into epidote which occurs in great abundance in the contact zone round the inclusions. Green epidote is also common as veins within the syenite.

Figure 31. Metamorphic schistose greenstone traversed by tourmaline rich pegmatite dykes. Loon Point south of Eastmain River.

The rock-complex of Paint Hills is worth a more careful petrographical investigation.

The same kind of basic rocks as at Paint Hills composes the rock-ground of Cape Hope Islands (28), the most extensive area of rocks of this kind. From a distance they give the impression of effusives, probably in part with a pillow structure. No landing was, however, made and therefore the question must be left open.

South of Cape Hope a few occasional landings were made of which only one gives any additional data to the information already given by Low. The small island outside Loon Point, visited by Low, consists partly of similar basic schists as those of Cape Hope Islands. They are injected by granite and transformed into amphibolite schists and micaceous schists. A number of large pegmatite dykes, very rich in tourmaline in beautiful crystals, traverse the basic rocks (Fig. 31). Tourmaline seems to be a common mineral in the region and has been brought from the interior by natives to the Hudson Bay post of Old Factory. It has also been mentioned by earlier explorers.

North of the mouth of Rupert River the islands (32) are composed of banded vein-gneisses of bluish-gray colour with layer-veins of granitic composition. They are rich in garnet and also seem to contain cordierite.

Petrogenetic conclusions.

The scattered observations here reported do not permit any detailed petrogenetic discussion of the rock-ground and therefore only some brief general points will follow.

I have, by describing a number of rock localities, tried to show the gradual change in the composition of the rock-ground from north to south along the coast of Hudson Bay — James Bay, from Portland Promontory to Rupert

River. At a superficial consideration the differences appear insignificant, but they are of a certain interest.

The middle section of the area, the south and east coast of the Belcher Basin shows very advanced granitization and, so far as can be deduced from the few reports from the interior, the percentage of granitic rocks seems to increase from west to east. Whether we assume that the granites and granitic gneisses were formed by means of plutonic intrusions, as immense batholiths, or by means of a replacement *in situ* of earlier supercrustal schists at a gradual advance of a »granite front», it is reasonable to imagine that this part of the coastal region represents a very deeply cut section through the granitic core of the continent.

South and particularly north of this highly granitized region we meet a rock-ground, still very granitic but also containing rocks showing structures (»palimpsest» in Sederholm's meaning) which can still be identified as belonging to supercrustal formations of a different kind. These palimpsests indicate that the basal formation of the rock-ground all along the coast from Portland Promontory up to Rupert River once had about the same composition, yet their remnants to-day occur in different metamorphic disguise.

In the northernmost section of the area at Portland Promontory the bed-rock is characterized by the great part played by pyroxene occurring as chief mafic component also in fragments of basic rocks in the migmatite granite. Also garnet bearing mineral-associations are common and farther soapstone serpentine, chlorite, talc are abundant. The granitic component of the rock-ground is characterized especially by a wide distribution of aplite granites and pyroxene bearing granite gneiss with albitic plagioclase. All the rocks show more or less strong plastic deformation with flowage structures originated in the solid state.

In the southerly parts of the east-shore of Hudson Bay and James Bay hornblende-bearing rocks predominate. The basic fragments of the migmatite gneisses are generally composed of amphibolite and hornblendite. Remnants proving that pyroxene was a primary constituent of the rocks, but was later replaced by amphibole, are not rare.

This difference in mineral-facies can be observed even where the general megascopic aspect of the rock exposures is very similar.

The mineral-facies of the Portland Promontory is evidently the same of pyroxene-hornfels facies grading into the granulite-facies. By side of these high-temperature associations comparatively poor in hydrous minerals there are serpentine-chlorite rocks representing the green-schist facies. The pyroxene-

hornfels facies rocks often grade into amphibolitic rocks. In the southerly areas the amphibolite-facies predominates.

To a certain extent the amphibolite facies seems to replace the green-schist-facies of the northern region and represent in the same way as the last named a later alteration of the pyroxene-bearing rocks. The general textural features show that we nowhere have primary rocks which have not been affected by a complete recrystallization.

It is interesting to note that the high-temperature facies predominates in regions where the old supercrustal rocks are comparatively well preserved; the amphibolite-facies where the granitization is more complete. This seems at the first glance to correspond well to the conception of Bowen about the transformation of a high temperature facies in a lower, at the contact of a granitic magma. At Portland Promontory, however, also small basic inclusions in the granite and the granitic gneisses are pyroxene-bearing. This seems to point to a general high-temperature metamorphism of the whole area including both the basic rocks and the granitic rocks. As was pointed out this facies, though very common in other places, is altered into low-temperature associations and the conclusions above only illustrate the main tendency in the origin of the bed-rock.

The relative scarcity of hydrous minerals here hardly can be explained by absence of water but rather must depend on conditions preventing the water to enter into silicate minerals during the high-temperature metamorphism.

At last at a temperature corresponding to the green-schist-facies the water and solved silica could react with the mafic minerals giving rise to serpentine, chlorite, etc. The serpentinization of the ultra-basic rocks has often been interpreted as primary and such an explanation might be correct for the serpentine bodies within the folded sediments in the Porpoise Cove area. On the other hand we have seen that minerals like garnet and actinolite formed at the granitization are also altered into serpentine and chlorite, in which case these minerals must have been formed much later, coinciding with the final stage of the regional metamorphism of the rock-ground. The observation material is unfortunately so far insufficient to permit any definite conclusions concerning this question.

There evidently is a connection between the different facies of metamorphism and the tectonic development of the rock-ground. We have in the northern region where the supercrustal formations are preserved at least two different stages of tectonic movement. The earlier one, which can be studied in the Port Harrison series at Porpoise Cove is characterized by a

type of folding and rock deformation often found in more recent mountain folding zones with a strong foliation and small folding.

The later phase of deformation coincides with the mise-en-place of the granite and is characterized by extremely plastic movement within the felsic rocks grading into flow-structure. The mafic rocks have, evidently due to greater resistance, not been foliated to any great extent, but are only broken up into angular fragments. The first type of deformation has affected the basic rocks about as much as the mafic ones.

This different behaviour of different rocks in the both cases evidently depends on the greater depth at which the later deformation took place, and can be studied in most deeply eroded regions in the pre-Cambrian. The difference in resistance between mafic and felsic rocks is evidently much greater at high temperature than at low temperature, the granitic rocks attaining a high degree of plasticity at conditions where the basic rocks still are rather rigid.

The pyroxene facies of the rocks probably was formed during an early stage of the deformation of the granitic gneisses. Later and above all where the homogenization of the granitic rocks is complete the amphibolitic phase seems to be more important. A more detailed discussion of these problems can be made at first when enough information about the structural geology of the region is obtained in order to carry out the tectonic analysis of the rock-ground. Before that a petrographic analysis has a purely academic interest.

The stratigraphic position of the Archaean rocks of the east shore of Hudson Bay.

The small fragments of the earlier supercrustal rocks of the region do give a very incomplete picture of the distribution of different rock-types. The most conspicuous feature is the great extension of basic intrusives and extrusives and the wide distribution of a banded iron formation. In connection with the last-named there evidently was some carbonate-rocks of which to-day only very small remnants are left. There may have been sandstones or other detrial sediments — greywackes — but if so they have been completely granitized.

There, however, is a greater similarity between these formations and the Keewatin than the Grenville rocks. Also the dominating east-west direction of the schistosity coincides with the same of the post-Keewatin folding in northern Ontario and Quebec.

I here want to point out the importance of the old iron formation of Ungava as a possible source of the iron material now forming the proterozoic iron-ores of central Labrador. The last named may in regions where they are highly folded be difficult to keep apart from the older iron formation and a precaution in that respect is advisable at the field-mapping.

Compared with the north coast of Labrador the region described in the foregoing pages so far as the rock-ground is concerned offer several conspicuous differences. The anorthositic rocks are absent and the quartzitic sediments in the rock which are a typical constituent in the archaean of the north coast are rare. Basic dykes of late pre-Cambrian age are much less numerous, and represented only by the vertical diabasic dykes related to the Belcher and Nastapoka series.

Also the type of metamorphism is different. In northern Labrador the garnetiferous rocks are much more common. Pyroxene bearing rock facies corresponding to the granulite-hornfels facies are found in greater extent at first in the northern regions.

Some notes concerning the contacts of the proterozoic sediment of the eastern part of Hudson Bay.

The proterozoic sediments of the eastern part of Hudson Bay have been the subject of a rather detailed investigation and description by Low, and my time being very short, I paid comparatively little attention to the petrology of this formation, and can contribute very little to the good descriptions already published.

Yet the great importance of this group of rocks for the structure of the coastal region makes it necessary to discuss certain questions concerning the relation between the late pre-Cambrian and the archaean rock-ground.

Low states in his paper on Nastapoka Island that the sediments have been the subject of a slight folding which has not affected their petrographical character to any considerable extent. He thinks that this folding is due to a pressure of the sediments against the archaean rocks of the coast and explains some non-conformities in the region of Richmond Gulf as due to thrusting.

The opinion of Low as to the relation between the proterozoic rocks and the older rocks and expressed in his general description of the coast is not quite clear, but he is evidently tempted to believe that the late pre-Cambrian rocks have been influenced by the granites and consequently may in parts be older. This argument is more emphatic in the description of the Nastapoka Islands, and is put forward as a reason for not calling the sediments Cambrian

but pre-Cambrian. I cite Low: »the granites which have been classed as typical Laurentian, always cut and alter the bedded rocks wherever seen in direct contact with them and are consequently newer than the latter. The above observed facts extending over large areas of the peninsula (Labrador) the result of several years study of rocks, have led the author to conclude that the term Cambrian as applied to these unaltered rocks is a misnomer, as, considered in their relation to the surrounding areas classed as Laurentian and Huronian, they are of similar or greater age than the rocks so classed; and the term Cambrian is confined elsewhere to rocks of more recent formation than the Laurentian or Huronian.»

This statement of an experienced geologist is of great interest, even if most geologists to-day do not agree with him concerning the age relation between the sediments and the old granite. Unfortunately it is not possible from Low's description to find out where he has seen the granite crossing the sediments, but it seems as if he refers especially to observations in the interior parts of the peninsula. It is also evident that Low did not make any definite difference between the old greenstones of the archaean formations and the diabases penetrating the younger formation, and regards them all as altered latepre-Cambrian intrusions. On his map all basic schists of the Port Harrison region are marked with the same colour as the diabases on the islands outside, which is certainly not correct, but understandable on account of the less advanced stage of the theories concerning metamorphism at the time of his journeys.

The different opinion expressed by Manning and Gunning concerning the age of the basic rocks of Cape Smith on one side and the Ottawa Islands on the other shows that the question even to-day is not always easy to answer, owing to the similarity of lavas from very different geological times.

Concerning the relative age of the granite and the sediments and lavas of the Nastapoka series on the east coast of Hudson Bay I have nowhere found evidence favouring the opinion of the younger age of the granites, but quite definite evidence that at least the normal »Laurentian» granite of the coastal region is older, and composes the base on which the proterozoic sediments have been layered. Although I believe that this opinion is to-day fairly generally adopted by geologists who have visited the area, I think it is worth while to give some descriptions of places where the relationship can be studied. The necessity of care in this matter is shown by mistakes made in other parts of the world in estimating the relative age of late pre-Cambrian formations of an age closely corresponding to the sediments here in question.

In eastern Greenland there is a rather sharp boundary between the slightly

altered sediments of the so-called Eleonora Bay series (Proterozoicum) and the underlying highly crystallized rocks penetrated by granites. This circumstance gave rise for a long time to the opinion that the crystalline complex belonged to an older formation. Investigations by the Danish expeditions 1920—35 (Backlund, Wegmann, Kranck, etc.) have, however, shown that the boundary is only the limit of the granitization (granite front), and the basal material of the crystalline formation is actually the same rock as the sediment above.

Descriptions of contacts.

As is often the case, it is difficult to find contacts between the Proterozoicum and the Archaean and I do not think earlier explorers have given any description of the contact itself. Low quite correctly states that the lowest layers of the sediments at Castle Peninsula at Richmond Gulf consist of an arcose which seems to have been formed by the disintegration of the granite of the interior of the country. He thinks this disintegration has taken place almost in situ. This shows that he differentiates between an older granite occurring at the bottom of the sediments and a younger granite penetrating them although the field evidence given is not quite clear, and both granites have never been described separately.

I had the opportunity to study an area about 6 miles north-east of Great Whale River (14) on the mainland where some remnants of the young sediments are seen in their original position on the old base. This spot is inside Bill of Portland Island, which consists of quartzitic sandstone overlaid by a thick bed of basalt with columnar jointing. There is also, outside the mainland coast about 200 feet from the shore, some small islands consisting of white sandstone.

The contact is very interesting because it shows a proterozoic shore de-

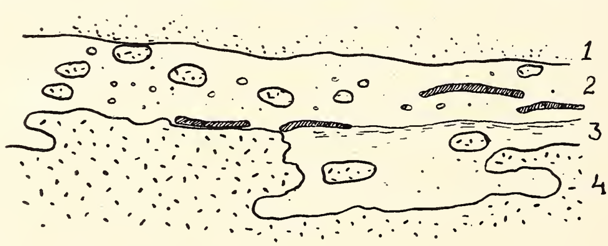


Figure 32. The contact between archaean granite and overlying proterozoic quartzite west of Great Whale River showing weathering cavities in the granite. 1. Quartzite. 2. Arcose with clay fragments. 3. Cavities with quartzite. 4. Granite. Scale 1 : 20.

position of a kind which could quite well have been formed at the present time on the shore some feet from the outcrop. Resting directly on the almost horizontal but slightly uneven archaean surface there are first layers of a pebble conglomerate some tens of inches thick, alternating with black or dark gray layers of mudstone-slate with ripples and sun cracks. The pebbles are granite and quartz. The whole series is only a few feet thick.

Figure 33. Horizontal fissuring in the granite underneath the proterozoic sediments. West of Great Whale River.

Over this basal conglomerate is an almost white sandstone of quartzitic appearance, of the same type as on the islands outside.

In some places in the exposure there are vertical joints which permit the study of the relation between the underlying granite and the conglomerate and show that the former was slightly weathered at the formation of the shore deposits and had not its present smooth ice-polished surface.

There are cavities containing the original weathering gravel consisting of the granite itself, covered by stratified sediments. The sketch Fig. 32 gives a picture of this condition. There is also in the granite in some places a peculiar pseudo-layering, formed by a strong horizontal jointing which gives rise to a strong disintegration of certain parts of the rock and is evidently due to the same lateral weathering (Fig. 33). The disintegration resembles in some degree that found in rapakivi granites though here not due to the texture of the rock itself. Pegmatite dykes cutting the granite have been affected by the same process but generally to a lesser degree. They are broken up into fragments, and crossed by fine fissures filled with pyrite.

The microscopic investigation shows a gradual change of the grain shape of the gravel resting on the weathered granite surface from very angular to more rounded and resorbed. Generally the mineral grains, except the quartz and in parts the microcline, are strongly carbonatized. The plagioclase is replaced by calcite or a turbid mass probably consisting of kaoline. Mica is altered into sagenite or a brown iron oxide, as is also the hornblende. The same type of alteration, but to a decreasing degree farther downwards, is also found in the underlying granite.

The weathering after all is not very strong and the climatic conditions at the time of its formation were evidently rather temperate.

Thus everything goes to prove that we here have a primary contact which

Figure 34. Brecciation on the »sub-Nastapoka» land surface on the shore cliffs west of Great Whale River.

has not been influenced in the slightest degree by later tectonization, regardless of the vertical jointing which can be found everywhere and which will be illustrated by some other examples.

On the coast west of Great Whale River I studied the contact near the Black Whale River (15) (a small Bay a couple of miles west of this harbour). Here the contact was not visible but the distance between the sediments in the lower strata and the granitic basements was only some meters. If there is a sandstone layer on the contact it is covered with drift. The sediments and the limestone lie in their original position relative to each other, with a slight dip towards the sea and there is no indication of movement, and no traces of later granitization.

On the coast between Cape Jones and Great Whale River some other features are also visible which show that the archaean rock surface now forming the shore-cliffs corresponds very nearly to the old sub-proterozoic land surface. Everywhere can be seen — particularly beautifully at Cape Jones and on the coast west of the mouth of Great Whale River — a system of joints generally more or less at right angles to the coastline. The joints are some tenths of an inch to some inches thick, sometimes forming bifurcations and crack systems giving rise to breccias, Fig. 34. They are filled with yellowish dolomite, quartz (chert) or pyrite. The first mineral is particularly characteristic for the western parts of the coast especially Cape Jones where the overlying layers of sediments consisted of limestone or where the limestone horizon in every case was near

Figure 35. The silicified and weathered archaean bedrock underneath the proterozoic quartzite of Knox Island SW of Port Harrison.

the bottom of the formation. The pyrite may be due to the comparatively high content of sulphur in some of the sedimentary layers. As in the sediments the pyrite seems as concentric concretions (Wasserkies) and was evidently deposited by solutions at low temperature. No other sulphides were found in the veins studied. The galenite-bearing veins of Richmond Gulf, Little Whale River and other places may be formed in connection with igneous intrusions. As, however, I have not seen these veins myself I do not want to make any statement about them.

The direction of the cracks in the rock-ground indicate, that they have been formed in connection with the folding of the Belcher-Island sediments which have been pushed against the coastal sediments giving rise to slight folding and especially faulting along the present coastline and causing the tilted position of the layers and also of the underlying archaean surface. This push has opened tension fissures transversal to the coast at a certain angle to the direction of the stress-movement; they have then been filled with mineral substances which leaked out from the overlying sediments.

Unfortunately I did not have the opportunity to study the contact relations of the Nastapoka series with the archaean on the coastal section between Great Whale River and Hopewell Sound where conditions are evidently a little more complicated on account of the stronger tectonization. Instead I made some studies in the Hopewell Sound areas where the conditions very much resemble those of the southern section. On Knox Island (3) in the central part there is an exposure of the archaean close to the proterozoic sediments which are here represented by a rather coarse-grained quartzitic sandstone. The underlying rock can be studied some feet from the quartzite and consists of a schlieric gneiss with vertical dipping schistosity. The rock on the surface is evidently considerably silificified but also contains abundant yellow carbonate (Fig. 35).

In other places especially the coast east of the Hopewell Narrows the

underlying archaean bedrock is exposed on the shore cliffs. Here tension joints are rather rare, indicating that the tectonic movements have been insignificant, a conclusion which can also be drawn by studying the sediments themselves. Nowhere could indications be found of granites intruding in the sediments.

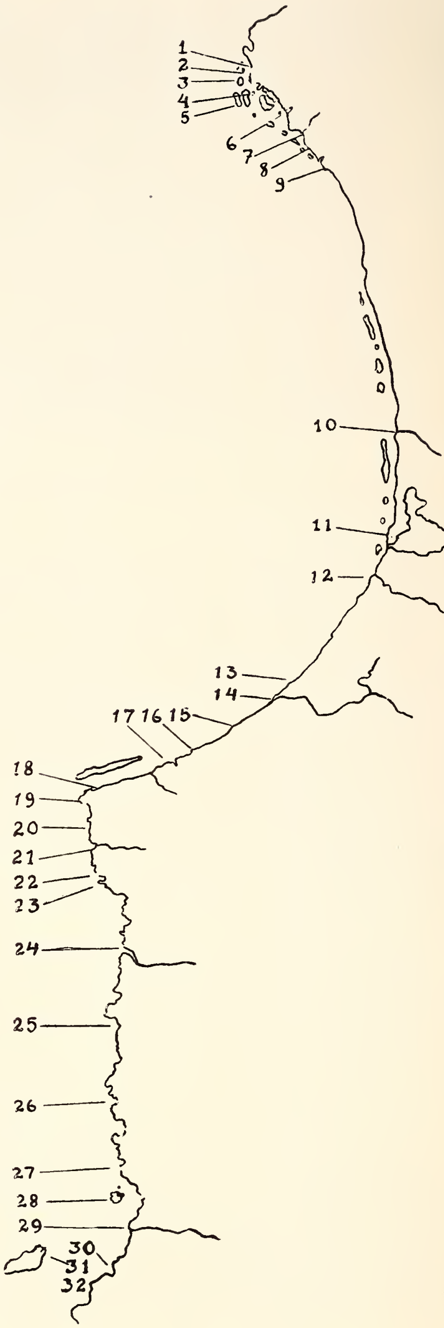


Figure 36. Sketch map showing the position of the localities described.

Summary.

The present report is based on observations carried out during a reconnaissance journey along the east coast of James Bay and Hudson Bay the summer 1947.

The geomorphology of the coast is described and the origin of the land forms is discussed. The importance of crustal movements during tertiary time is emphazised. The present coastal relief is believed to depend chiefly on these movements in addition to the late pre-Cambrian folding of the Belcher sediments.

Some observations concerning the glacial-geology are briefly quoted. Dune formations of the east coast of Hudson bay are described.

The old pre-Cambrian rockground of the region is mainly granitic with inclusions of basic intrusive and extrusive and

highly granitized sediments. East of Port Harrison a supercrustal series overlied by the proterozoic sediments was found, which consists of mica schists, amphibolitic schists, ultrabasic rocks and a banded iron formation. Traces of the same iron formation is found as remnants in the migmatite gneiss so far south as Cape Jones and it may occur in greater amount in the central parts of Labrador. Precautions should therefore be taken not to confound this old iron ore with highly folded types of the proterozoic iron formation.

The metamorphic facies of the rocks at Portland Promontory seems mainly to be granulitic ore diopside-hornfels, farther south the amphibolite facies predominates.

Some contacts between the Nastapoka series and the underlying archaean gneisses are described. No traces of tectonic deformations caused by thrust-movements could be found. The granites of the region are everywhere older than the Nastapoka sediments and volcanics (diabases and related rocks).

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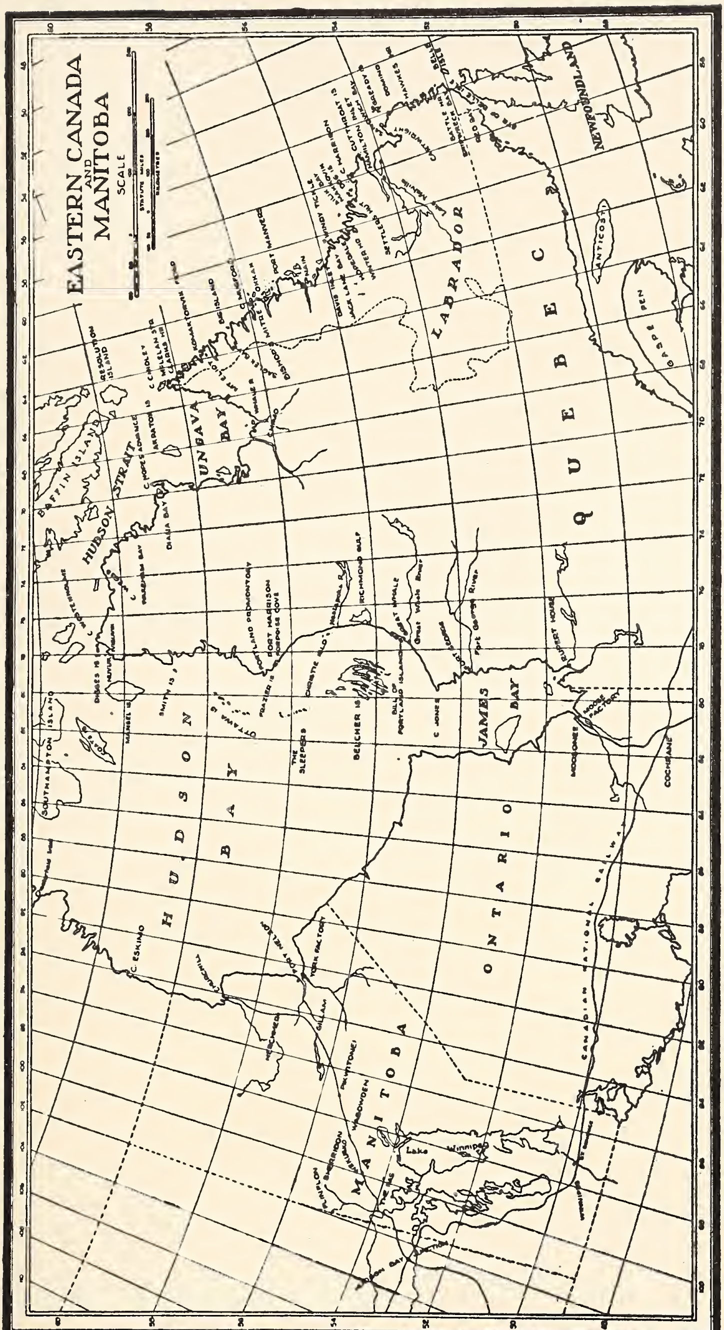
EASTERN CANADA AND MANITOBA
SCALE
HUDSON BAY
HUDSON STRAIT
UNGAVA BAY
JAMES BAY
LABRADOR
QUEBEC
ONTARIO
MANITOBA
NEWFOUNDLAND
ANTICOSTI
GASPE PEN
BAFFIN ISLAND
SOUTHAMPTON ISLAND
RESOLUTION ISLAND
BELCHER IS
YORK FACTORY
CHURCHILL
C ESKIMO
MOOSE FACTORY
RUPERT HOUSE
COCHRANE
CANADIAN NATIONAL RAILWAY
Lake Winnipeg
THE PAS
BELLE ISLE
NAIN
HOPEDALE
PORT HARRISON
RICHMOND GULF
GREAT WHALE
MOOSONEE
MANSEL IS
DIGGES IS
FRAZIER IS
THE SLEEPERS
C JONES

ACTA GEOGRAPHICA
11

Text 154 pages; 3 maps, 7 diagrams, and 64 figures in the text.